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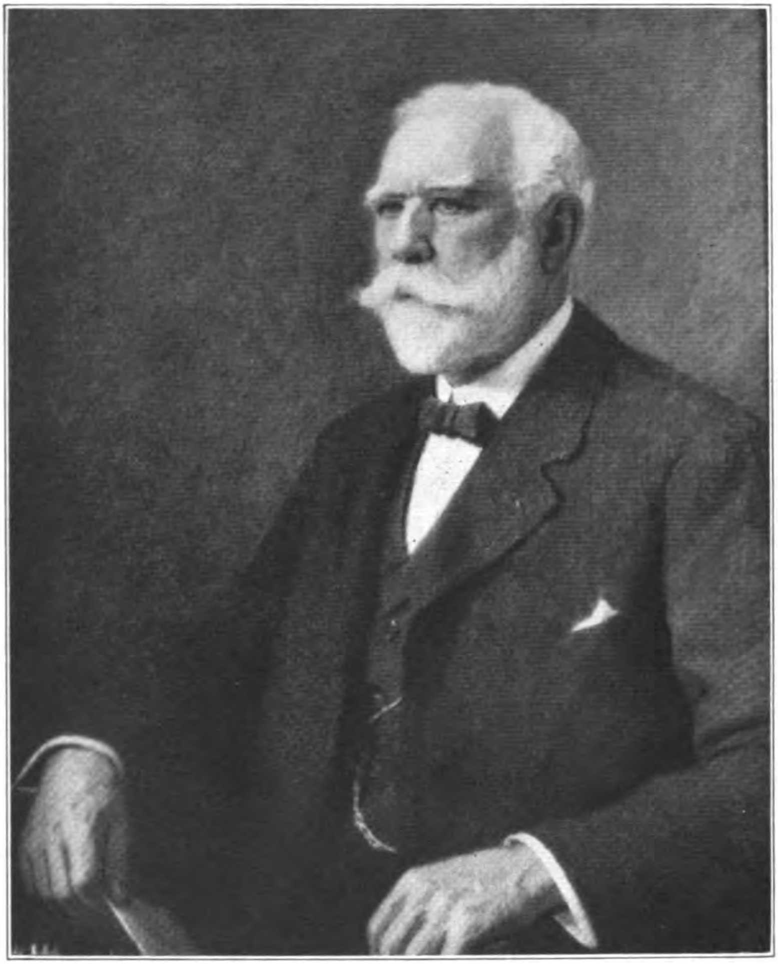

WILLIAM SELLERS,
PRESIDENT, 1864–1866,
Member, Board of Managers, 1857–1861, 1867–1892,
From a painting by William John Whittemore,
presented to the Institute by Mr. Alexander Sellers, 1928.

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Devoted to Science and the Mechanic Arts

Vol. 206 JULY, 1928 No. 1

THE SEMI-CENTENNIAL OF THE WORLD'S FIRST TESTS OF THE DYNAMO.

As is well known, the dynamo as an instrument for the production of electrical currents is about one hundred years old. It was known and used by various investigators but was never tested before 1877. In the winter of 1877–78 three different makes of dynamos were tested in the Hall of The Franklin Institute, Philadelphia—photometrically, mechanically and electrically, for the first time in the world's history. The machines tested were Gramme machines, Wallace-Farmer machines and Brush machines. As a result of these tests the Committee recommended the purchase by the Institute of a Brush machine, which had shown an efficiency of thirty-one per cent. That instrument is now in the possession of the Institute. The tests were carried out by a committee from the members of The Franklin Institute, made up as follows:

J. B. Knight, Secretary of the Institute, Chairman; Dr. Robert E. Rogers, President of the Institute; Prof. Pliny Earle Chase, Professor of Philosophy and Logic, Haverford College; Robert Briggs, Consulting engineer; Dr. Edwin J. Houston; Dr. Elihu Thomson; Theodore D. Rand, lawyer; Washington Jones, engineer; Samuel Sartain, artist and engraver.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

The electrical tests were made by Professors Elihu Thomson and E. J. Houston, the results of which were published in full in the Journal of The Franklin Institute.

On April 18, 1928, the Institute held a set of exercises in celebration of the semi-centennial of these original dynamo tests. A group of distinguished and representative scientists gathered in the afternoon of that day in a meeting which was addressed by Dr. Charles F. Brush, inventor of the original arc light system of illumination and of the arc light dynamo purchased by the Institute, and inventor of the first practical storage battery; and Professor Elihu Thomson, inventor of the Thomson-Houston arc light machine and the world's original 'dynamo tester.'

The meeting in the afternoon was followed in the evening by a dinner given in honor of the two speakers. The papers which were read at the semi-centennial exercises follow.

SOME REMINISCENCES OF EARLY ELECTRIC LIGHTING.

BY

CHARLES F. BRUSH, Ph.D., LL.D., Sc.D.,

Member of the Institute.

THE present period of human civilization is often called the "Age of Electricity." Almost everything nowadays is done by, or with the aid of, electricity. The applications of electricity have profoundly modified and enriched human life. And all of this change (except the telegraph) is embraced in a period of fifty years; a period well within the memory of the older generation now living. To better realize the extent of the revolution that has occurred in everyday life, try to imagine ourselves today without any electric light; without the telephone or radio; without the trolley car, or electric elevator for our high buildings; without the many domestic electrical conveniences; without industrial electro-metallurgy; without the vast distribution of cheap power we now enjoy, and without hydro-electric development of our waterfalls. A rather gloomy picture of life only fifty years ago.

I am often asked what first drew my attention to the electric arc-light—a mere laboratory curiosity not so very long ago—what inspired my belief in its industrial possibilities, and led me to work out the many necessary inventions which finally led to commercial success.

These questions are not readily answered. Keen but passive interest in the brilliant experiments of Sir Humphry Davy, and others of later date, followed by much thought, study, and experiment, led gradually to the fixed idea. It was an evolution covering a period of years.

From early boyhood I was an omnivorous reader of scientific literature. Such parts of astronomy, chemistry, and physics as I could understand were a never-ending source of delight. I also constructed much crude apparatus —telescopes, microscopes, and photographic appliances.

In my early high-school days I made, among other things, many pieces of electrical apparatus—static machines, Leyden

jars, batteries, electromagnets, induction coils and small motors. But the electric arc as described in the text-books, with its dazzling light and intense heat, was for a long time beyond my reach. Not until 1865 was I able to produce a real arc-light, a very small one indeed; but it was the first I had ever seen, and it filled me with joy unspeakable. I had to make the necessary Grove batteries for the purpose, using lumps of gas retort carbon instead of the customary strips of platinum which I could not afford to buy. In the early seventies I constructed a first-rate induction coil of unique design, giving very fat four-inch sparks. It had only six miles of *bare* secondary wire so wound that contiguous turns could not contact.

Soon after my first little arc-light, came the news of Wilde's experiments in London with his crude dynamo and single arc-light. The light was probably about the size of our ordinary street lights; but it was deemed a wonder at that time, and interested me so much that I wrote a graduation essay on it the following year (1867).

In the early seventies the Gramme dynamo made its appearance in Paris. It was the first really efficient dynamo, and excited wide-spread interest. Some stores and factories were lighted by it at that time, but a separate dynamo and complicated clockwork lamp were required for each light, and these were too expensive for general use.

Some queer notions about the electric light were prevalent. As late as 1873, Deschanel's "Natural Philosophy," a well-known text-book, said: "The light of the voltaic arc has a dazzling brilliancy, and attempts were long ago made to utilize it. The failures of these attempts were due not so much to its greater costliness in comparison with ordinary sources of illumination, as to the difficulty of using it effectively. Its brilliancy is painfully, and even dangerously intense, being liable to injure the eyes and produce headaches. Its small size detracts from its illuminating power—it dazzles rather than illuminates—and it cannot be produced on a sufficiently small scale for ordinary purposes of convenience. There is no mean between the absence of light and a light of over-powering intensity."

The advent of the Gramme machine interested me deeply,

and from that time the industrial possibilities of dynamos were never out of mind.

Early in 1876 I completed drawings for a dynamo of my own designing. This turned out to be a distinctly new type, since known as the "open-coil" type, preëminently well fitted for production of the high-tension currents necessary for series arc-lighting, which developed later.

Such parts of that first dynamo as required machine-shop work were made under my direction at the shop of the Telegraph Supply Company, and together with necessary materials were shipped to my old country home near Wickliffe, Ohio, where I spent my summer vacation in 1876. There, in the little workshop where I had made my first crude electrical apparatus in boyhood days, I wound the armature and field-magnets, and completed the machine.

The day of trial was a memorable one for me. I belted the little dynamo to an old "horse-power" used for sawing wood, and attached a team of horses. After a little coaxing with a single cell of battery to give an initial excitation to the field-magnets, the machine suddenly "took hold," on short circuit, and nearly stalled the horses. It was an exciting moment, followed by many others of eager experiment. That was my first acquaintance with a dynamo.

This pioneer machine was long preserved, and formed a part of the United States Government Historical Exhibit at a subsequent Paris Exposition.

The little dynamo was next taken to the shop of the Telegraph Supply Company, where steam power was available, and testing work was continued, while plans for further development were beginning to take shape. A small clockwork arc-lamp was constructed and used with the dynamo.

My personal friend, Mr. George W. Stockley, was president of the Telegraph Supply Company, and he agreed with me that there were very promising commercial possibilities in development of electric light. Thereupon business arrangements were made by which the Company undertook commercial exploitation of the new dynamo and such other electrical inventions as I might make.

In the autumn of 1876 the Telegraph Supply Company began the manufacture of dynamos of the new type adapted

to electroplating. A considerable business was developed in this direction. It is of historical interest that my compound field winding for constant potential, so generally used in incandescence lighting and power transmission, was first applied to plating machines. It was, in fact, invented for that purpose in the autumn of 1877.

During the autumn and winter of 1877 and 1878 two of the new dynamos built for lighting were exhibited and tested at the Franklin Institute in Philadelphia. In connection with the dynamos, a new lamp of very simple construction was also exhibited. This, since known as the "ring-clutch" lamp, was the first simple lamp which appeared, and it marked a very great advance in the art. Costing perhaps a quarter as much to make as other lamps then used, it was far less liable to derangement. Its salient features have been embodied in nearly all arc-lamps ever since.

During the testing of the two Brush dynamos and others, and the Brush arc-lamp in the fall and winter of 1877–78, I visited the Franklin Institute several times and made the acquaintance of Professor Elihu Thomson who conducted the tests. This was the beginning of a warm personal friendship which has continued unabated through fifty years.

The first dynamo and lamp actually sold by the Telegraph Supply Company were shipped to Dr. Longworth of Cincinnati about January, 1878. I went down to Cincinnati to show the Doctor how to run his machine, and one evening while I was there he exhibited the light from the balcony of the building in which he lived, on one of the principal streets. It was a four-thousand-candle light, and of course, attracted a large crowd, every man of which was ready and willing and eager to tell his neighbors all about it. I mingled in the throng for a time to hear the comments. One man who had collected a considerable audience called attention to the solenoid at the top of the lamp and said, "That is the can that holds the oil"; and, referring to the side rod, said, "That is the tube which conducts the oil from the can to the burner." He said nothing at all about electricity—a little oversight apparently unnoticed by his hearers; they went away happy in their newly acquired knowledge of the electric light.

The early single-light machines were quickly followed by two- and four-lighters: that is to say, machines furnishing two or four separate and distinct currents, each adapted to operate a single arc-lamp.

Then began the tedious education of the public to the new light. The principal difficulty arose from the propensity of everybody to stare directly at the arc, and then declare that everything else looked dark. It took years fully to outgrow this habit. I had often to ask, "Why don't you stare at the sun if you wish to be dazzled? It is vastly brighter than the electric light." Furthermore, most early purchasers of electric lights thought each lamp giving as much light as fifty gas-burners would replace fifty gas-lights, notwithstanding the great advantage of distribution possessed by the latter. Altogether too much was expected.

However, a number of two- and four-light units were sold during the season of 1878 for lighting stores and shops. The largest plant of this kind, about twenty lights, was bought by Mr. John Wanamaker for his great department store in Philadelphia.

A four-light dynamo and lamps were used to light a part of the Mechanics' Fair in Boston in the autumn of that year. The electric light was a novelty in Boston at that time, and a great attraction at the fair.

One of the earliest four-light machines was exhibited to a number of invited guests at the works of a large manufacturing company in Cleveland. One gentleman on that occasion looked the whole apparatus over very carefully for perhaps half an hour, and then, pointing to the line wire, said to me, "How large is the hole in that little tube that the electricity flows through?" The shop superintendent of the company observed the machine for perhaps five minutes in complete silence; then he had fully digested the whole matter, and was ready to explain it to me. He said: "The electricity is generated by that there revolving affair rubbing the air up against them iron blades (meaning the pole-shoes of the magnets), just as you get sparks when you rub a cat's back." I suggested that while his was a simple and beautiful theory, it did not fully meet the facts. But he would hear nothing from me. He said: "The whole thing is plain. If you

should run that machine in a vacuum, where there is no air to get rubbed, you couldn't get any electricity."

The year 1878 was a memorable one in the history of electric lighting. Not only did it witness the first industrial use of electric lights on any considerable scale, but it was in that year that I had the great good fortune to invent and develop the modern series arc-lamp with its regulating shunt coil. It was this invention that made arc-lighting from central stations commercially possible; and I think it may justly be regarded as marking the birth of the electric-lighting industry.

It had become evident by this time that a "fool-proof," or nearly fool-proof, lamp was essential to commercial success. The users of lamps could not be induced to let them alone, and no end of trouble was caused by meddling with them. So, in designing the new series lamp, I endeavored to make it completely fool-proof, and nearly succeeded, but not quite. The mechanism was locked together like a Chinese puzzle, and difficult to get apart. It was entirely devoid of screws that could be taken out and lost, or adjusting devices with which users could tinker. All necessary adjustments were made in the shop when the lamp was tested, and were made permanently. But of course it was possible to take a lamp apart, and in this sense it was not fool-proof. Complaining of a lamp which failed to operate, a man once said to me, "Why I've had that lamp all to pieces four times, and yet it won't work."

The high-tension dynamos for series lighting were "fool-killers," and usually able to look out for themselves. They discouraged undue familiarity.

Of course "series" lighting immediately superseded "parallel" lighting. A single large dynamo and one lamp circuit were much cheaper, simpler, and more easily managed than several small dynamos and many lamp circuits. Furthermore, the line cost and losses were vastly less, thus permitting the location of lamps at any desired distance from the dynamo —miles, if necessary. The stimulation of the business by the introduction of series lighting was enormous.

The first series plant, a six-light outfit, was sold in December, 1878, for lighting a clothing-store in Boston. One of the lights was hung over the sidewalk in front of the store,

and nightly attracted crowds of people. This was the first electric light ever used in the streets of Boston.

Quickly following the six-light machines came the sixteen-lighters; and they remained the standard size until late in 1880, when they were followed by the forty-light machines.

One of the earliest sixteen-light outfits was installed, in February, 1879, in a worsted-mill at Providence, Rhode Island; another was purchased in March, another in April, and two more in September, making eighty lights in all—the largest electric light plant in the world at that time. Other purchasers of plants in 1879 were mills in Providence, Hartford, and Lowell, a hotel in San Francisco, and several New York dry-goods houses.

Many plants were sold in 1880, and by the end of that year about six thousand lights had been installed.

Of course it was difficult to educate men fast enough properly to install and operate the plants, and much annoyance was caused by trivial accidents and poorly constructed and poorly insulated lines, which led to "short circuits" and "grounds." It often fell to my lot to straighten out these troubles. Once I traveled fifteen hundred miles to take a common staple tack from the bottom of a dynamo, where it happened to short-circuit a field-magnet. Sometimes malicious tampering with the dynamos occurred, but, fortunately, not often. Long, fine wire nails were occasionally found driven into the field-magnet coils in inconspicuous places.

Some difficulties were never traced to their source. On one occasion sixteen lamps were returned by our Boston agent with the statement that his men were quite unable to make them work decently. I examined and tested the lamps carefully, and found them all right. Without making any change or adjustment whatever, except to change the numbers so as to conceal their identity, I sent the lamps back, with a letter stating that I had personally examined and tested this lot, and could guarantee them to be all right. They were put back in their original places, and worked beautifully, so the agent said; and he requested me as a personal favor to look over all lamps he might order in the future before they were shipped. He wanted to know what was the matter with the first set, but I never told him.

We had much trouble with carbons in the early days. Our first carbons were crooked and soft. They had high electrical resistance, burned out rapidly, and were very expensive. They were made from gas-retort carbon, which was difficult to pulverize, and contained from three to five per cent. ash. The ash was fatal to the steadiness of the light, causing the arc to flicker badly. It was necessary to find some better material than gas-retort carbon without delay.

After much anxious thought and prolonged study of industrial processes likely to yield such material, I hit upon "still coke," a by-product of the destructive distillation of mineral oils. As the result of many analyses of different specimens of this substance, it was found that by careful selection the ash could be kept as low as two or three hundredths of one per cent. Still-coke could be pulverized with comparative ease, and was obtainable in unlimited quantities at small cost. It has ever since been almost everywhere used in making carbons.

But the early carbons made from still-coke shrank enormously in baking, and consequently were very crooked. Much experimenting was necessary to find out how best to work with this material. Then, too, special machinery and furnaces had to be designed for grinding, mixing, molding and baking. These details occupied much of my time during the first two or three years.

To decrease their electrical resistance and retard the burning of the carbons, we electroplated them with copper. This little scheme of covering the carbons with just enough, but not too much, copper was the only easy invention that it was my privilege to make; and it paid well, considering its seeming simplicity. It yielded, if I remember correctly, something like $150,000 in cash royalties before serious competition set in.

The very early carbons were sold at the rate of $240 a thousand. I say at the *rate* of $240 a thousand, because nobody thought of ordering a thousand carbons at once. Fifty or a hundred were ordered at a time. When the business increased a little, we reduced the price to $150 a thousand. This involved loss for a time, then covered cost,

and afterward afforded profit as the business grew larger. We soon again reduced the price, this time to $62.50, on the theory that cheaper carbons would stimulate the growth of the electric-light industry; and our expectations were abundantly justified. The growth of the lighting business was very rapid from that time on, so that while we lost money on carbons at first, we far more than made it up in increased sales of dynamos and lamps. After a while, however with largely increased and growing output, we made a handsome profit.

During the first ten years or so of the electric-lighting business, the price of carbons gradually settled down to about ten dollars a thousand, and remained not very far from that figure. But the quantity used grew to amazing proportions. Before the introduction of the "inclosed-arc" lamp, the annual consumption of carbons reached nearly two hundred millions.

The first instance of permanent public-street lighting anywhere in the world was in the Public Square of Cleveland, a little park of about ten acres. In April, 1879, twelve lamps of the ordinary so-called two-thousand-candle power were installed in the park on high ornamental poles.

While we were putting up the poles and line circuit, a great deal of interest was manifested by the public, and on the evening when the lights were formally started the park was crowded with people. Many evidently expected a blinding glare of light, as they had provided themselves with colored spectacles or smoked glass. Of course there was at first a general feeling of disappointment in this respect, although everyone was willing to admit that he could read with ease in any part of the square. After a few weeks, however, when the novelty had worn off, and the people had tired of staring at the lamps, the general verdict was highly favorable to the new light.

As the Public Square lights were required to burn all night, this necessitated putting fresh carbons in each lamp sometime during the night, because a single set would not last until morning. But the nightly trimming of the lamps required an extra man and added materially to the cost of lighting. To meet this difficulty, I devised the "double-

carbon" lamp, which afterward grew into general use for all-night lighting, and became famous through much patent litigation.

The new lights were exhibited in London in 1880. For that purpose we sent over a sixteen-light outfit and some smaller ones. The English capitalists whom we sought to interest were incredulous at first, and would not believe that sixteen powerful lights could be operated by one dynamo, certainly not in a single circuit. They thought some trickery was behind it. But they were soon convinced, and the Anglo-American Brush Electric Light Corporation, Limited, was organized to exploit the new industry in England and throughout Europe. The corporation was capitalized at eight hundred thousand pounds, and started a large manufacturing plant in London.

The earliest public lighting in London was that of the Houses of Parliament, Charing Cross Station, Ludgate Hill Station, Blackfriars Bridge, and St. Paul's Churchyard.

The industry experienced a rapid growth during the next two or three years, but was afterward greatly hampered by adverse legislation limiting the electromotive force of lighting circuits. This was thought to be instigated by the gas interests. In the meantime the lights were introduced on the Continent, and also in India, Australia, and other British possessions.

In the early summer of 1882, The Brush Electric Company of Cleveland gave a public exhibition of arc-lamps in the main street of Tokio. It was the first time arc-lights had been seen in Japan, and they excited great interest.

This exhibition was followed by several large contracts with the Japanese government. The first was for lighting the navy-yard and docks at Yokosuka, on the Bay of Tokio, at that time the only navy-yard in Japan. Another was for lighting the Tokio arsenal, where the small arms for the army and navy were manufactured. This contract was made with General (later Field Marshal) Oyama, who was then Minister of War. Another contract was for lighting the government woolen-mills near Tokio, where the cloth for army and navy uniforms was manufactured. Search-lights for the chief vessels of the Japanese navy were also supplied.

In the summer of 1882 the Shanghai Electric Company was organized to light the foreign municipality of Shanghai, China. This was the first central station organized anywhere in the Orient. The Company started with about a hundred arc-lights.

Starting with public-street lighting in Cleveland early in 1879, the central-station idea rapidly took root, and before the end of 1881 lighting stations were in operation in New York, Boston, Philadelphia, Baltimore, Montreal, Cleveland, Buffalo, San Francisco, and several other cities.

Perhaps the largest of the early stations was that of the Brush Electric Light Company of New York, located at 133 and 135 West Twenty-fifth Street. On December 20, 1880, Broadway from Fourteenth to Twenty-sixth street was first lighted from this station, with a circuit nearly two miles in length. Fifteen lamps were used, mounted on ornamental iron poles twenty feet high, and placed at the street intersections. A few weeks later the lights were extended to Thirty-fourth street.

The lights were the ordinary nominal two-thousand-candle power then in vogue; but the lamps gave this amount of light only when measured in the zone of greatest illumination. The average horizontal illumination was about eight hundred candles, and not quite uniformly distributed in all directions.

Not long afterward some of the lights were measured by a famous college professor and patent expert employed by a gas company. Naturally he did not select the most favorable conditions for measurement, and in his report stated that he thought the electric-light company must have arrived at its two-thousand-candle power rating by measuring the lights north, south, east and west, getting five hundred candles each way, and adding all together.

The opposition of the gas companies everywhere was moderate at first, but became strenuous when central-station lighting began to develop, and continued several years.

I argued from the first that the general introduction of arc-lights in cities would greatly stimulate the consumption of gas, on the ground that the public, becoming accustomed to brilliantly lighted streets and stores, would burn far more gas at home. This prediction, paradoxical as it seemed, was abundantly and admittedly fulfilled.

The name of the Telegraph Supply Company was changed in 1881 to the Brush Electric Company, capitalized at three million dollars, a very large corporation for those days.

The forty-light dynamos of 1880 were followed in due time by the sixty-five lighters. Next came the hundred-and-twenty-five-light machines, which long remained the standard Brush arc-dynamos, and came into general use for long-circuit series lighting from central stations.

Almost from the beginning of its commercial success, the Brush Electric Company met with vigorous competition, made practicable by the hostile attitude to all patents manifested by the Federal Courts. Prior to the early eighties it had been the custom of the Courts to sustain almost anything in the shape of a patent, and permit inventors to reissue and claim everything to which they were originally entitled. Doubtless in some cases great injustice was suffered by manufacturers and the public. Then came a sudden reversal of policy, and for about ten years no patents were sustained unless they had previously received favorable action. Inventors in every field of effort suffered from this cause before normal reaction came. In the meanwhile the fundamental patents covering electric lighting had nearly expired by limitation of their terms. All competitors in arc-lighting used the Brush series arc-lamp, more or less modified in appearance. It was indispensable. The most successful used the open-coil dynamo also.

The early success of arc-lighting undoubtedly prompted and hastened the development of incandescence lighting as well as power transmission and electric traction.

Incandescence lighting on a commercial scale came in 1882, about four years after the advent of the arc-light. But its coming had been loudly and continuously proclaimed by the Press for several years, to the great consternation of the gas companies.

In the very early years of electric lighting mine was strictly a "one-man" laboratory. I had no assistant; indeed no assistant was available. I made all the working drawings for the dynamos, lamps and special shop appliances needed. Wrote all the patent specifications. Tested and adjusted all dynamos and lamps. No time was wasted in superfluous sleep or recreation.

I was greatly hampered by the lack of electrical measuring instruments. I had only a Wheatstone bridge and galvanometer. Ammeters and voltmeters were unknown. About 1881 I designed and built a sturdy instrument of each kind for my own shop testing. They were of enormous assistance. I calibrated them by means of storage batteries and resistances of large coils of heavy dynamo magnet wire. The electromotive force of the storage batteries was ascertained by balancing them against "Daniel" batteries of supposed E.M.F. of 1.079 volts. Several hundred of each of these instruments, calibrated by comparison with my first ones, were later supplied to our Central Station plants. They became known as the "meat-scale" instruments.

I also designed an easily-used and reliable dynamometer to measure the driving power required by our dynamos with different loads.

Later, when the Brush Company began the manufacture of electric motors, I designed a perfectly automatic "Prony" brake to measure the power output. It could be set at any desired load, and would maintain that load closely constant as many hours as desired. The ends of the friction pulley were turned inward an inch or two toward the center, thus forming an annular chamber next to the rim of the pulley, into which water was poured from time to time after the motor was started. The water was held in place by centrifugal force, and boiled quietly with an apparently snow-white surface.

We are all familiar with the enormous development of electric lighting which has taken place during the last forty years, since the early days I have referred to.

I thank you for your attention and interest.

Duodecimal System. HENRY LEFFMANN (*Bull. Wagner Free Institute of Science*, 1928, *3*, 3–6) has summarized the advantages of the duodecimal system in a speculative essay. The base of the system is divisible without fractions by 2, 3, 4, and 6. The dozen and the gross are extensively used units in merchandizing. The system is now in use to a limited extent, as is shown by the following examples. The foot is divided into 12 inches, the inch into 12 lines, and the line into 12 points. The year has 12 months; the face of the clock has 12 major divisions; and 12 pence make a shilling. The fathom (6 feet) and the league (3 geographical miles) are really based on a duodecimal system. It is suggested that two new figures or signs be introduced between 9 and 10, that these signs be an inverted J and an inverted V, and that they be designated, respectively, as "kal" and "gan."

J. S. H.

Blast Furnace Slag as a Fertilizer. J. W. WHITE (Pennsylvania State College, School of Agric. and Exp. Station, Bull. 220, 1–19, 1928) has published a preliminary report on the agricultural value of specially prepared blast furnace slag. This slag has hitherto been a by-product of the iron industry of no economic value. It is now marketed in either granular or ground form. The granulated slag is known as agricultural slag and is obtained by running the molten slag into cold water with the production of small, brittle, porous fragments. The ground slag is manufactured from the air-cooled slag by a process of grinding to a fine powder. The slag contains silicates of calcium and magnesium; and its lime and magnesia content ranges between 45 and 50 per cent. It is readily soluble in dilute mineral acids, and acts as a source of calcium for plants and sweetens the soil when used as a fertilizer. Other constituents of the slag may have a stimulating effect on plant growth. In experiments with fourteen crops, thirteen gave greater yields with 20-mesh agricultural slag than with limestone. Granulated slag does not produce yields equal to those produced by limestone. The value of the slag depends on the degree of fineness and the rate of disintegration in the soil. One ton of the slag has been used per acre. In Pennsylvania, the consumption of agricultural lime is only about 20 per cent. of the amount that could be used to advantage. In certain parts of the state, agricultural slag may be available as a cheap source of lime.

J. S. H.

THE PIONEER INVESTIGATIONS ON DYNAMO MACHINES FIFTY YEARS AGO.

BY

ELIHU THOMSON, A.M., Ph.D., LL.D., D.Sc.,

Member of the Institute.

IN looking back over a period of something more than fifty years with an endeavor to picture in some degree the conditions, and especially the electrical status at that time, there are certain salient facts to be noted. Telegraphy over land and by submarine cables had at that time been well established. Deposition of metals, such as copper, in electrotyping, though in use in special instances, was still a comparatively young art, as also in silver plating or plating with a thin blush of gold. Nickel plating, comparatively new as an art, was beginning to grow in favor largely through the work of Weston, who also was early in the field in employing dynamo currents for this work, instead of the more usual Voltaic batteries; mostly of the Smee type.

Dynamo-electric machines, now called electric generators, were rare indeed and of crude design in most cases. The first I ever saw was a Wilde-Ladd machine in the collection of Prof. Robert E. Rogers, later one of our Committee charged with the dynamo tests, in the Department of Physics at the University of Pennsylvania. The recollection of the thrill it gave me to see two men turn the cranks and keep red hot a strip of metal by the current generated is still with me.

There were but two exhibits of dynamo-electric machines at the Centennial Exhibition held in Philadelphia in 1876. In the Machinery Hall was a small space devoted to an exhibit by Gramme of Paris, and another by the Wallace firm, of Ansonia, Connecticut. It is an interesting fact that the Gramme dynamo which figures in the Institute tests of 50 years ago was one of those in the Gramme space at the Centennial Exhibition. I well remember the sign over the Gramme exhibit and the enthusiasm of the French exhibitors or attendants when stating in French several uses of the

Gramme dynamo; "La Lumiere Electrique," "Le Transport de Force," "et la Galvanoplastie." There had been no effort at translation of these terms for the American public. Examples of each of these uses were shown at the exhibit. The electric light was, of course, the carbon arc light in open air in the Gramme space. No other form of electric light source was known as a practical thing at that time, and for some years whenever "the electric light" was referred to, it was the carbon arc light that was meant. Discussion of the subdivision of the electric light meant subdivision of the arc light, necessarily.

"Transport de Force" was illustrated by one Gramme dynamo furnishing electric current energy to another like machine, coupled to the shaft of which latter was a centrifugal water pump which raised water from a tank to a few feet elevation from which it flowed back, producing a waterfall effect, as a pretty illustration of power transmission. Reverse this plant, and magnify it without limit, and you have the modern hydro-electric system, the "white coal" of today. In addition, a special low voltage Gramme machine satisfied the requirements of the plating bath.

My remembrance is that the Wallace-Farmer dynamo at the Centennial Exhibition, driven by a steam engine, was occasionally used, as on special days, for working a single arc light on the roof of such a building as Machinery Hall for illuminating the grounds.

It is well known that the year of the Centennial of 1876, and the Exhibition itself are notable for the first demonstration of the speaking telephone by Alexander Graham Bell. This was the simple magnetic telephone surviving in the telephone receiver of today in universal use, and from which simple electrical device have grown the great telephone systems now existing all over the world.

A little light may be thrown on conditions before the telephone existed when, as I can state from recollection, the whole Western Union telegraph service of Philadelphia city about a year or two before 1870, was concentrated in a single office at the southeast corner of Third and Chestnut Streets. From this office messenger boys were sent out to deliver all over the city the messages received from other

points, while messages to be transmitted to the outside were brought by the sender to the counter in the office itself. I can give this statement a personal touch by relating that I, at the age of about sixteen, spent one of the dreariest nights of my life in lone charge of that office at Third and Chestnut Streets, from dark to dawn. During that whole night there were only two or three messages that were handed to me over the counter for transmission. It was my job to shoot them through a conveyor to the operator's room on the upper floor of the building. The office was finished and furnished in dark wood, and lighted sparsely by poor gas burners, while the office room itself was below the street level several steps. The weight of responsibility was added to that of the surrounding gloom and was very depressing. The street lamps outside at that time were illustrative of positions far apart but not of magnitude. However, it was an experience not soon to be forgotten. How the telephone and electric light have changed all that!

I may be pardoned by referring at this point to my own activities a few years later. In 1874 the Franklin Institute held an industrial exhibition in what was known as the old Pennsylvania Railroad depot at 13th and Market Streets, now the site of the great Wanamaker stores. Market street was traversed by railroad freight cars along a pair of tracks laid on granite sleepers embedded near the street center, from which tracks curved sidings entered the warehouses on the north or south sides of the street. Tandem lines of mules were the motive power for switching the cars to or from the appropriate sidings. This motive power was finally given up, though as a boy in my teens I well remember its operation.

The freight station itself was at 13th and Market, and this, having been rendered vacant, afforded an opportunity for the Franklin Institute 1874 exhibition. Though I was but 21 years of age, I was given the responsibility of a judge of awards in electrical and philosophical instruments. At this time I was teaching science in the Boys' Central High School, the old building at Broad and Green Streets, and was in charge of the chemical laboratory, later being made Professor of Chemistry and Mechanics there in 1876.

The confidence of the Institute was further exemplified in

the request that I should give, in the winter of 1876–77, a course of five lectures in Electricity, a subject in which I had been deeply interested from early boyhood. In these lectures, which were, as usual at the time in such matters, well illustrated by experimental demonstrations, I tried to show that electricity from whatever source, statical, voltaic, dynamical, magneto, etc., was the same in nature, differing only in conditions under which it was manifested. In other words, my general idea was to break down as far as possible what I regarded as unmeaning classifications and distinctions in electrical phenomena which were fundamentally alike if properly regarded; and to make easy the transition from one to the other, both theoretically and practically. Some of the apparatus used was original with me, and constructed by myself. At the present it may seem strange that any proofs of the identity in nature of the various forms of electric manifestation could ever have been needed, but the case was different half a century ago.

I have thus far been reviewing these early events before touching on the real subject matter of the dynamo tests of half a century ago. Perhaps it may serve to bring out a fact that accounts in a way for my being at this time the only survivor of the Committee on Dynamo Electric Machines of the Institute; all of the others were older than I was, and, I regret to say, have long since passed to the "Great Beyond." The men who constituted our Committee were eminent in their time in the various departments of science and engineering and were intimately associated with the activities and management of the Institute itself.

It is, however, a source of intense gratification to me that we can again greet our great pioneer in arc lighting, Mr. Charles F. Brush, of Cleveland, on this platform. Mr. Brush and I were the younger men at the time. Two of his early arc-light dynamos figured in the 1878 tests, one of which was, upon our Committee's recommendation, purchased for the Institute. Mr. Brush has distinguished himself not only in the electric field, but in his many scientific studies. To mention only one other of his pioneer achievements in electricity, we may take the modern storage battery, which has not been changed in any essential respect since his work

of invention and development, more than forty-five years ago.

Fifty years ago there were, of course, no electric supply stations and no ready means for securing electric currents for demonstrations, as for working an electric light with the carbon arc. Dynamos were few and far between. Instead, it was necessary to set up a series of fifty or sixty Grove or Bunsen cells for the purpose. This was a heavy task in itself, and to take them down after an hour or two of use, a worse one, demanding exposure to irritating fumes of nitrogen tetroxide, without gas masks, and involved the handling of large amounts of strong acids. I know well what this meant from actual experience in those early days. How easy it is now to tap the electric supply circuit and secure the electric energy needed for any purpose!

When, about 1877, the Institute had established in this hall a steam engine of about 6 horse-power for driving forms of machinery to be brought to the attention of the Institute, it was natural that attention should be turned to the acquisition of an electric current source. The age of electric applications was just beginning and the electric arc-light was far more convenient than the calcium or lime-light for such purposes as lantern projection. It was, therefore, determined that a dynamo suitable for the then present and prospective needs of the Institute be purchased. It was thought also that a general service might be rendered if tests could be conducted which might, at least in a general way, determine the electrical and mechanical properties of such machines, and also their applicability to the production of light in the use of the carbon arc as a source.

We are here to commemorate the fiftieth anniversary year of the series of tests made by the Institute Committee on Dynamo Electric Machines, the Report of which Committee was published in the JOURNAL of the Institute for May and June, 1878.

While, before this report was made, there were in existence some data on the power consumed by dynamos working single arc-lamps as used in a few lighthouses, and determinations of the candle power of the light produced (with similar sporadic tests), it has appeared that the Franklin Institute tests

constitute the first real investigations, comparative in nature for different machines, and complete enough to enable one to judge of the machines as more or less efficient converters of mechanical into electrical energy. The report was probably unique in the inclusion of electrical measurements as a special feature.

This part of the work was confided to Prof. Edwin J. Houston and myself as a sub-committee. The paucity of instruments suitable for such measures, and indeed the entire absence of such means, made it necessary to improvise to an extent quite inconceivable in these days. This condition of lack of instruments and standards remained acute even for a considerable number of years subsequent to 1878.

The unit of current in use was called the "Veber" or "Weber." Not till the International Conferences of 1881 in Paris was the name Ampère adopted for the unit of current. We already had the Volt and Ohm as international units and approximate standards.

In our report of losses in the machines tested, we designated as due to *local action*, power which disappeared in a machine and which could not be accounted for in the electric arc or any part of the electric circuit of the dynamo. In subsequent years it was found to be due to two causes, now well known as eddy current loss and magnetic hysteresis.

Fifty years ago, little was known of the waste of energy in changes of magnetism of iron now called hysteresis.

The tests clearly disclosed I believe for the first time that the measured resistance of arcs was, other conditions being the same, nearly in the inverse proportion to the current in the arc: an unstable load requiring that the machines, to maintain steady arcs, must have what was long after known as drooping characteristics, the characteristic being a curve showing the relation between the current in a series machine and its voltage or E.M.F.

Beyond a certain value of current generated the E.M.F. at the terminals of the dynamo must decrease as the current further increases and at a certain rate, so that the current becomes stable, without surges.

Another matter also brought out was that the internal resistance of the machine itself should be as low as possible

while the work resistance should be high in relation thereto, in order to secure the best efficiency in electrical energy output in relation to mechanical input.

These conditions are all so plain today that they seem self evident, but it took some years after the test for their significance to be generally understood.

The report itself reveals many of the particulars of operation not fully understood before.

It was in this hall that our Committee made the investigations which were embodied in the Report of May and June, 1878. As both Professor Houston and I were engaged in teaching at the Boys' Central High School for most of the day, and the tests had to be conducted after hours, so to speak, it will be seen that those were strenuous days of fifty years ago.

There is an acknowledgment I would like to make at this time as it may supplement to some extent at least, an unintentional omission in my address delivered with the history of the Institute given by me upon the occasion of its Hundredth Anniversary.

Prof. Monroe B. Snyder, who, fifty years ago, was in charge of the Astronomical Observatory at the Boys' Central High School, was much interested in the proposed dynamo tests of 1877–78, and discussed with me the methods to be pursued. His help and suggestions were of considerable value in the outlining of the work of our electrical tests. He followed closely in succeeding years the progress abroad in establishing the electrical units on a firm basis. At the time of the Electrical Exhibition in 1884, the first of its kind in America, and conducted as a Franklin Institute enterprise, he prepared an address on "The Establishment of a National Bureau of Physical Standards" for the Electrical Conferences held in Philadelphia in connection with the Exhibition of 1884.

Prof. Snyder's early address, with one of Lord Kelvin's, I believe, were the ones presented to the Senate Committee of 1900, which resulted in the establishment of the Bureau of Standards in Washington, the activities of which now cover so large a field. I regret that these facts were not presented in my historical review at the time of the Centenary of the

Institute, as they serve to connect the Institute with one of the major developments in science in our country, and to show that Prof. Snyder was early awake to the necessities of the case. Prof. Snyder, now over eighty, is still with us and still looking forward to the new advances.

During the half century since the time we are commemorating, there has been a vast development in many fields of science and industry, but the progress in the understanding of electricity, the great strides in its application, the enormous expansion of industries based on electricity, have been so phenomenal, that it is difficult to imagine that any future period can ever present such a record of achievement.

In that period there has been verified the idea that, after all, electrical actions, those of the electrons, are fundamental in explaining the relations between the different forms of matter themselves, and to energy.

Thirty years ago in a paper before the Franklin Institute, I ventured to suggest that we might come to regard all actions, even mechanical properties, as in their essence electrical. The criticism by one electrical journal was that it was natural that an electrician should wish to make all things electrical. But history has answered the question, and furnished the proof, as we now know. We accomplish unification, and to that extent simplification, but I think that there will always remain, in the growth of knowledge, more than we can ever explain.

By careful investigation and tests, such as those made fifty years ago, we acquire a basis for progress and, assisted by imagination, we are able to project our thoughts into new and fruitful fields. I remember saying to some younger men, after we had been working with so-called direct currents and had begun work in the alternating current field that the field offered by electricity in vibration would be boundless. In 1881 I had observed some curious high frequency phenomena, and in 1889 constructed probably the first high frequency dynamo made, and this was followed up in the next decade with numerous experiments in that novel field, by Mr. Tesla and myself.

We see in radio actual applications on the widest scale

of these early results, such that the schoolboy may talk of kilocycles, radio frequency, audio-frequency, inductance, capacity and the like terms, in the new electric art. Let us hope that he is real student enough to learn just what they mean.

Can we doubt that the future will have in store for mankind many triumphs following the earnest application of the scientific method? This may be succinctly expressed in the words "Prove all things and hold fast to that which is good."

When I prepared the foregoing statements I was unaware that we should be favored with the presence at these exercises of so many who have been identified with electrical progress within the period of years since 1878.

As a representative of these I may mention my co-worker since the early days when at the time of the tests he was yet a pupil of mine at the Boys' Central High School and one of the most promising, Dr. E. W. Rice, Jr. Also Dr. Frank J. Sprague whose pioneer work in the development of electric railways did so much to establish the electric motor as the power for traction. I first met him as an exhibitor at The Franklin Institute Electrical Exhibition of 1884 as I clearly remember. He hasn't much changed since then.

What Becomes of Stellar Radiation? BOHUSLAV BRAUNER and J. H. JEANS. (*Nature*, April 28, 1928.) Sir Oliver Lodge has asked "What becomes of the radiation which the stars are continually pouring into space?" Professor Brauner of Prague comments thus: In view of the consequences of Einstein's theory of relativity "to-day space must be regarded as finite. If a straight line starts from a star it does not go straight to infinity, but returns to the original source. I beg to conjecture or suggest that the radiation from the star may behave like the straight line and be brought back to its origin again, after having travelled around the universe." For this journey Jeans allows 10^{11} years, but, the stars being calculated to be much older than this, a sufficient time has elapsed for at least the earlier part of their radiation to have made the trip and returned to the source, unless it was intercepted by other stars on the way.

Jeans agrees that light can "travel round and round in an Einstein universe," though not in the universe according to de Sitter. While admitting that some part of the radiation emitted by a star does re-enter it after the journey around the universe, he holds the fraction to be very small. "If it were nearly unity we should see a star in every direction in space, and the sky would be a uniform blaze of light. If even one part in 100,000 of their light fell back into the stars, the night would be half as bright as the day."

Jeans does not share the difficulty felt by Lodge and Brauner as to the fate of radiation, since the annihilation of all the matter in the universe would raise the temperature of space only about 11.5° C. "Space is so vast by comparison with the matter it contains, that discussing the ultimate fate of radiation seems rather like discussing the ultimate fate of a few lumps of sugar dropped into the Atlantic." He sees much difficulty in believing that stellar radiation can create new matter. The amount of energy requisite to produce a hydrogen atom is .0015 erg. To emit a quantum having so much energy a temperature of about 75×10^{11} degrees would be needed.

G. F. S.

RECENT PROGRESS IN THE THEORY OF BAND SPECTRA.*

BY

EDWIN C. KEMBLE, Ph.D.,

Jefferson Physical Laboratory, Harvard University.

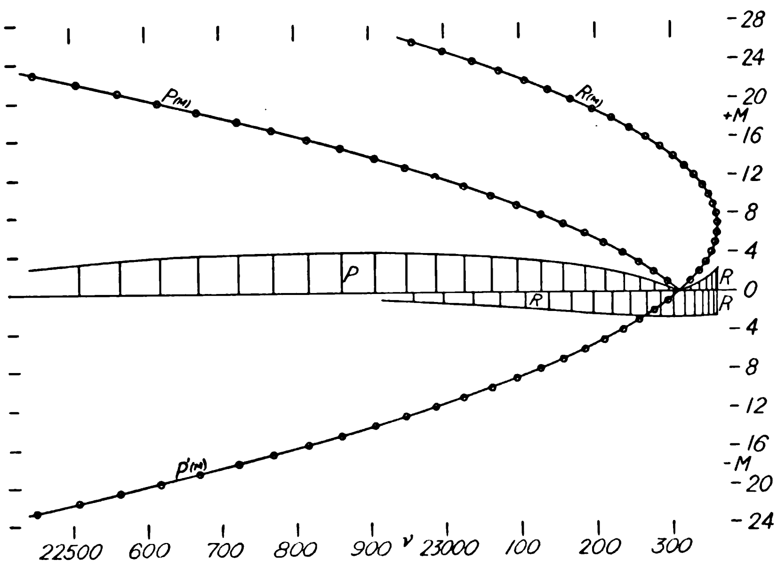
GASEOUS spectra are divided into two classes which we conventionally call line and band spectra. These names are based on a difference in appearance illustrated by Figures *a* and *b* of Plate 1, but are somewhat misleading since both types of spectrum are seen to consist of fine discrete lines, when examined by a spectroscope of high resolving power. The line spectrum is really the spectrum of a single species of atom or of a monatomic molecule. The study of spectra of this type has been the most important single key to the solution of the problem of the structure of atoms. Band spectra are emitted by molecules containing two or more atoms and hence we frequently (and more accurately) refer to them as "molecular spectra." Their study is of the greatest importance in helping us to understand the structure of molecules, the nature of valence forces, and the detailed mechanism of chemical reactions. Recent progress in the application of wave or quantum mechanics to the problem of band spectra and molecular structure has been so great that it seems not chimerical to hope that in a few years we may understand the fundamental principles of molecular formation as definitely as we now understand the principles of dynamo design. If this hope is realized only mathematical difficulties will prevent us from making a deductive science of chemistry. Unfortunately, however, there is little prospect that the mathematical difficulties will be overcome in any wholesale manner.

Thus far the study of band spectra has been largely confined to a consideration of those originating in diatomic molecules since the spectra of more complicated species are so complex that they are of little use. Even the diatomic bands are discouragingly complex in many cases as will be

* Presented at a meeting held Thursday, March 29, 1928.

evident from such a "close-up" as Fig. *d*, Plate I. A simpler example is shown in Fig. *e*, Plate I. The lines in the left hand portion of this figure are evidently arranged in a regular manner in two overlapping series. This regular structure is conveniently brought out by making a plot, or Fortrat diagram, such as that shown in Fig. I. Here the abscissas

FIG. I.



Fortrat diagram for λ 4280 CuH band. From Chapter IV of Report on Molecular Spectra in Gases (Bull. National Research Council No. 57, 1926).

are the line frequencies, or reciprocal wave-lengths, and the ordinates are the ordinal numbers of the lines in the series to which they belong. Fig. 2 shows a similar diagram for a more complicated case.

In the spectrum of an individual molecular species we have, of course, not one band such as those just discussed, but many. These are arranged in a regular manner in groups or systems (Fig. *b* and *f*, Plate I) and there may be many systems in the complete spectrum of a molecule. Thus the molecular spectrum may be regarded as organized according to the following plan, or hierarchy:

Spectrum

↙ ↘

Systems

↙ ↘

Individual bands

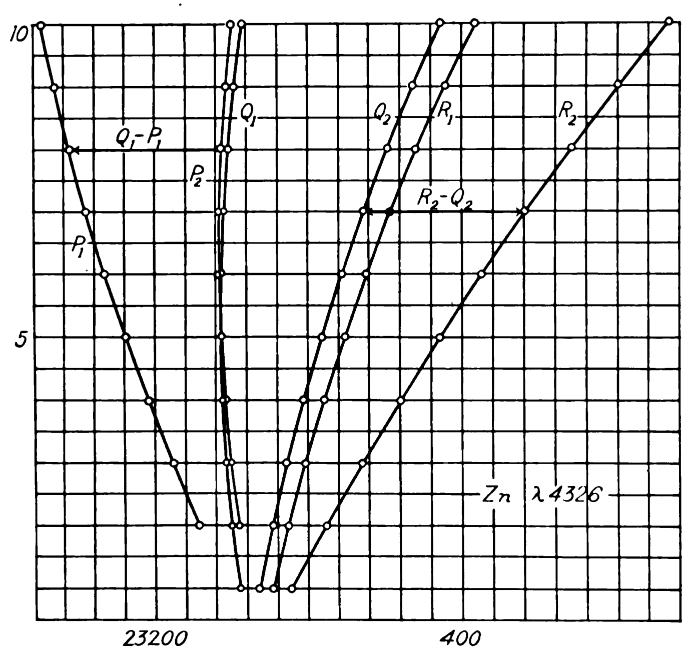
↙ ↘

Band series

↙ ↘

Individual lines

FIG. 2.



Fortrat diagram for λ 4326 ZnH band. From Hulthén's thesis, Lund, 1923.

According to our present conception of things the energies of atoms and molecules are not continuously variable but are restricted to certain discrete values or energy levels. The emission of radiation occurs only as an accompaniment to a discontinuous jump from one such energy level to another,

the wave-length and frequency of the radiation being determined by the famous rule of Einstein and Bohr:

$$E' - E'' = h\nu.$$

Here E' and E'' are the initial and final energy values of the molecule, h is Planck's constant, and ν is the vibrational frequency (equal to the velocity of light divided by the wave-length). On account of the above relation the possible values of E fix the possible frequencies of the spectrum and conversely the frequencies determined experimentally may be used to locate the energy levels.

FIG. 3.

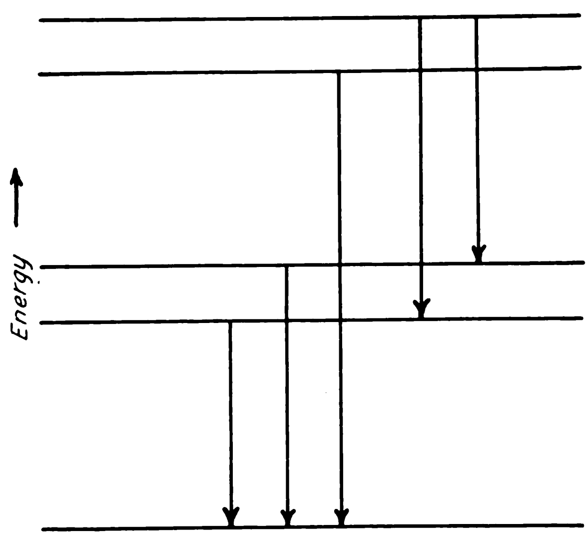
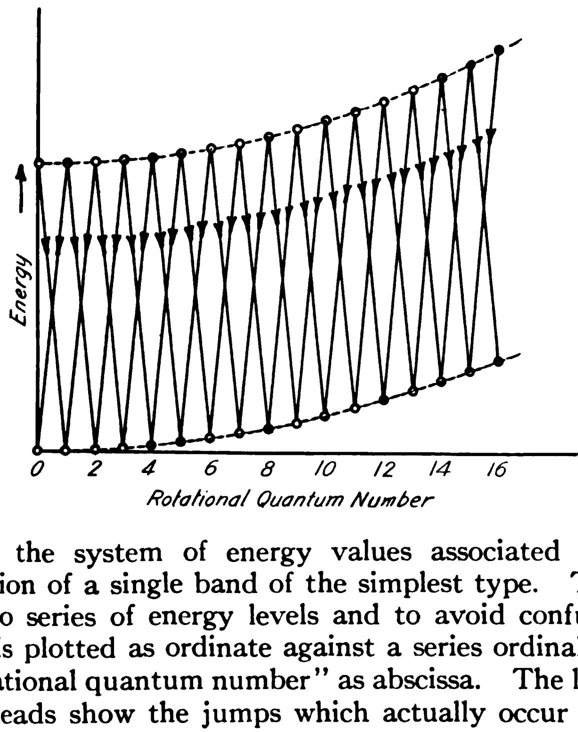


Fig. 3 shows graphically the relation between the energy levels and frequencies in an artificially simplified case. Energy is plotted vertically, the horizontal lines being energy levels. The vertical lines show the jumps which produce the different wave-lengths in the spectrum. The lengths of these lines are proportional to the radiation frequencies and inversely proportional to the wave-lengths.

The system of energy values of a molecule may be worked out from its spectrum in many cases and is both more simple

and more fundamental than the spectrum itself. The location of the energy levels is the fundamental problem of the spectroscopist. There are many energy values for any molecule but fortunately they are organized in a way that parallels the organization of the spectrum itself. Fig. 4 shows a small

FIG. 4.

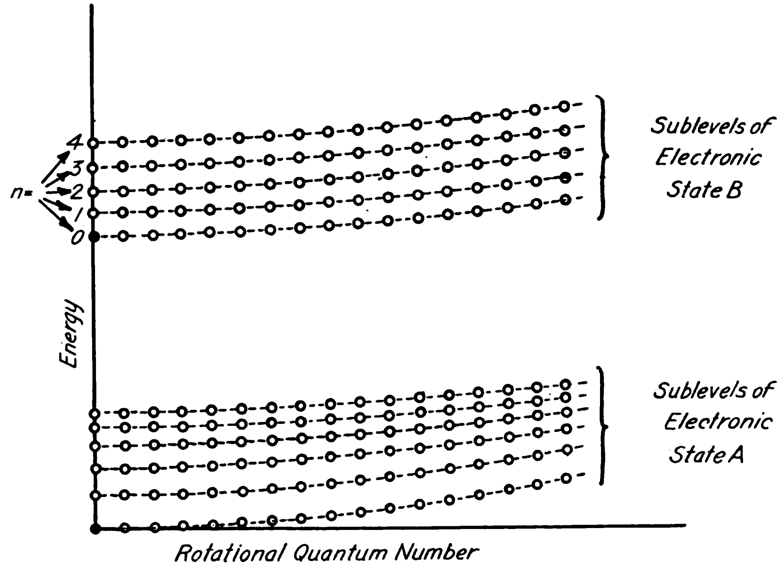


part of the system of energy values associated with the production of a single band of the simplest type. There are here two series of energy levels and to avoid confusion the energy is plotted as ordinate against a series ordinal number or "rotational quantum number" as abscissa. The lines with arrow heads show the jumps which actually occur and lead to spectrum lines. It will be observed that owing to a "principle of selection" only a few of the very large number of possible transitions actually take place.

Fig. 5 illustrates in a general way the organization of the complete system of energy levels of a molecule as empirically determined. There are many such series as shown in Fig. 4 and these are organized into series of series. The numbers n in the figure are the ordinal numbers of successive members of one of these superseries. It should be understood that the diagram is simplified by the artificial termination of both

types of series and by the omission of minor complications which frequently occur.

FIG. 5.

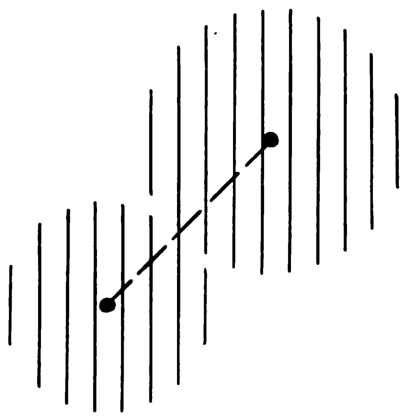


Let us now consider for a few minutes the theoretical interpretation of the empirical energy level scheme. A qualitatively satisfactory interpretation was first worked out on the basis of the classical quantum theory of Bohr and Sommerfeld. In this theory it was assumed *first* that the motions of the parts of the atom or molecule in any given energy state take place approximately in accordance with the laws of classical mechanics; *second* that the motion is always a combination of periodic motions like the motion of a point on the earth's surface resulting from the annual rotation of the earth about the sun, the monthly rotation of the earth and moon about their center of gravity, and the daily revolution of the earth about its own axis; *third* that among all the possible motions permitted by the classical mechanics only those actually occur which satisfy certain mathematical rules or "quantum conditions" which relate the spacing of the energy values to the periods of the motion. These rules like nearly all fundamental laws in physics are devised to fit the experi-

mental facts and are justified only through the large number of such facts which they correlate. I will not bore you with their mathematical formulation but will content myself with a brief description of the way in which they work out when applied to a diatomic molecule.

Our atomic model, as you all know, consists of a heavy central positively charged nucleus around which moves a swarm of from one to ninety-two electrons with motions at least approximating those of planets. The diatomic molecule we assume to consist of a pair of such atoms held together by forces which vary with the distance between the nuclei in

FIG. 6.



such a way that atoms may vibrate back and forth along the center line as well as rotate about the center of gravity. The energy of such a molecule may be arbitrarily divided into three parts as follows: First there is the energy which the molecule would have if the nuclei were neither vibrating nor rotating. This energy has relatively widely spaced discrete values determined primarily by the frequencies of the orbital motions of the electrons. Then there is the energy of vibration of a molecule which is not rotating. The spacing of the vibrational energy values is proportional to the vibrational frequency and is normally smaller than the spacing of the electronic energy levels. When the spacing of these levels is measured experimentally we can determine from it the frequency of vibration and so obtain information regarding the

law of force for the attraction and repulsion of the atoms in the neighborhood of their equilibrium point. This varies from one electronic energy level or electronic state to another. Finally there is the rotational energy which also has discrete values but with a still smaller spacing than the vibrational energy values. The rotational energy values are determined by the moment of inertia of the molecule and from their experimentally measured spacing we may discover the moments of inertia of the molecules in their various electronic and vibrational states. In particular we may discover the moment of inertia of the non-vibrating molecule which is related to the atomic masses m_1 and m_2 and to their equilibrium separation r_0 by the formula

$$I_0 = \left(\frac{m_1 m_2}{m_1 + m_2}\right) r_0^2.$$

Thus it is possible to fix the normal internuclear distances of the various electronic states of molecules with considerable precision by band spectrum measurements. We obtain in this way, for example, the value 2.663×10^{-8} cm. for the normal iodine molecule, 3.015×10^{-8} cm. for one of the excited states of iodine, 1.279×10^{-8} cm. for normal HCl, etc.[1]

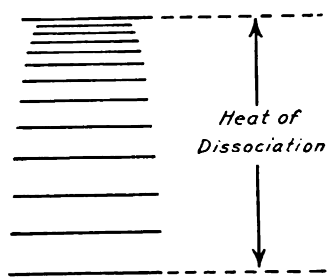
The energy values plotted on Fig. 5 are of course made up by various combinations of electronic energy, vibrational energy, and rotational energy. The dotted lines connect levels having a common electronic and vibrational energy but differing in rotational energy. From the spacing of the levels in one of these series we determine the moment of inertia and the mean distance between the nuclei. The lower group of energy levels is associated with a single electronic state A, the upper with another electronic state B. The different series in, say, the upper group differ in vibrational energy and the spacing of the levels indicated by circles on the vertical axis is a measure of the frequency of vibration of the molecule in the electronic state B. The lower left hand level in each

[1] A summary of the molecular constants derived from band spectra is given in Section 7 of the chapter on "Electronic Bands" by Birge in the Report on Molecular Spectra in Gases issued by the National Research Council (Bulletin No. 57, Dec. 1926). A longer and more complete table also prepared by Birge will appear shortly in the International Critical Tables.

group (solid circle) corresponds to a molecular state in which the vibrational and rotational energies are very nearly zero. The spacing of these levels is the difference in the electronic energies of states A and B.

The values of the fundamental constants of the molecule determined from the band spectrum may be checked in other ways such as by the measurement of the specific heats and free energies of gases,[2] but no other method is as precise as the spectroscopic one where the latter is available. It is also possible to determine spectroscopically the magnetic moments and gyroscopic properties of the molecules but there is not time here for a discussion of this detail.

FIG. 7.



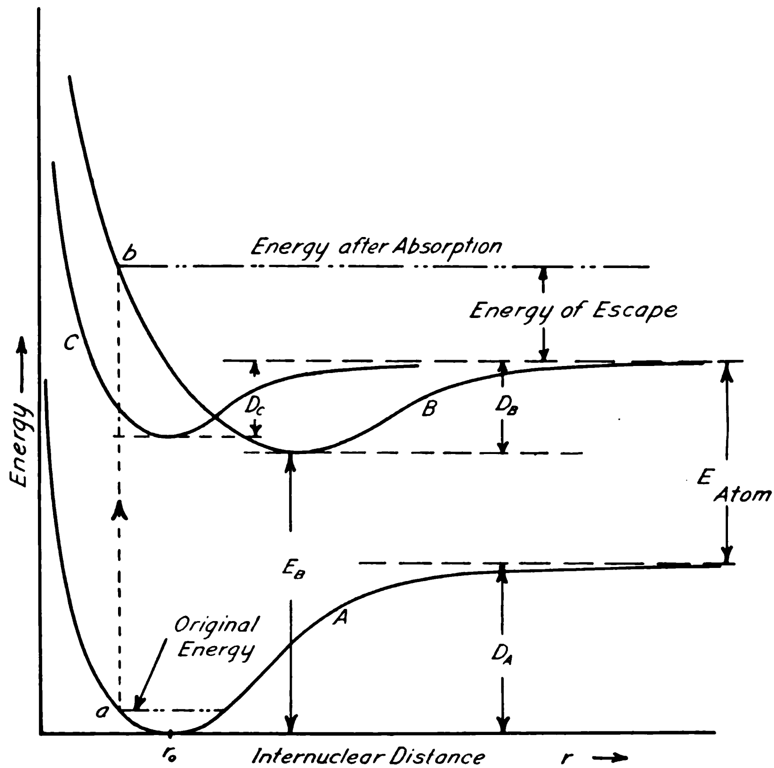
Of major importance, however, is the optical measurement of the heat of dissociation of a molecule or the energy required to pull its constituent atoms apart.[3] This energy is tied up with the system of vibrational energy levels (see Fig. 7). When the vibrational energy of a molecule is steadily increased the amplitude increases also, and the atoms come nearer and nearer to escaping from each other at the end of the out swing. As disruption approaches the period of vibration becomes very long. The spacing of the vibrational levels accordingly approaches zero as the energy of vibration approaches the heat of dissociation as a limit. A graph of the vibrational energy values has therefore the appearance indicated in Fig. 7 and the heat of dissociation may be read off

[2] Cf. for example, D. M. Dennison, *Proc. Roy. Soc.*, **A-115**, 484 (1927); Hicks and Mitchell, *J. Am. Chem. Soc.*, **48**, 1520 (1926).

[3] Cf. Birge and Sponer, *Phys. Rev.*, **28**, 259 (1926); H. Sponer, Ergebnisse der Exakten Wissenschaften, Bd. **6**, 75 (1927).

from it directly if the energies have been fully determined by experiment. Usually complete data are not available but even then we may frequently locate the convergence point of the energy level scheme approximately by a process of extrapolation.

FIG. 8.



Having measured the normal internuclear spacing, the frequency of vibration, and the energy of dissociation of an electronic state we are in a position to draw up a good approximate curve for the mutual energy of the two atoms as a function of the distance between them. This curve has normally the general appearance of the three shown in Fig. 8. Its slope gives the force of attraction or repulsion between the atoms. At large distances it has a small positive slope asso-

[4] J. Franck, *Trans. Faraday Soc.*, 21, 3, 1925.

ciated with an attractive force, while at sufficiently small distances the force must be repulsive and the slope negative. The minimum point locates the equilibrium value of r and may be determined from the moment of inertia. The curvature near this point fixes the frequency of vibration for small amplitudes and may be determined experimentally from the vibrational energy scheme. The heat of dissociation locates a horizontal asymptote to the curve for infinite r while the axis of ordinates constitutes a vertical asymptote for zero r. For the rest we know from the regularity of the spacing of the vibrational energy levels that the curve is normally smooth. Hence a clever draughtsman can draw in a pretty good approximation to the mutual energy curve on the basis of the elementary measurements I have sketched. A more detailed analysis of the experimental data will, of course, make possible a more accurate curve involving less guesswork. Fig. 8 shows three such curves for three possible electronic states of a molecule. Each has its own moment of inertia, frequency of vibration, and heat of dissociation.

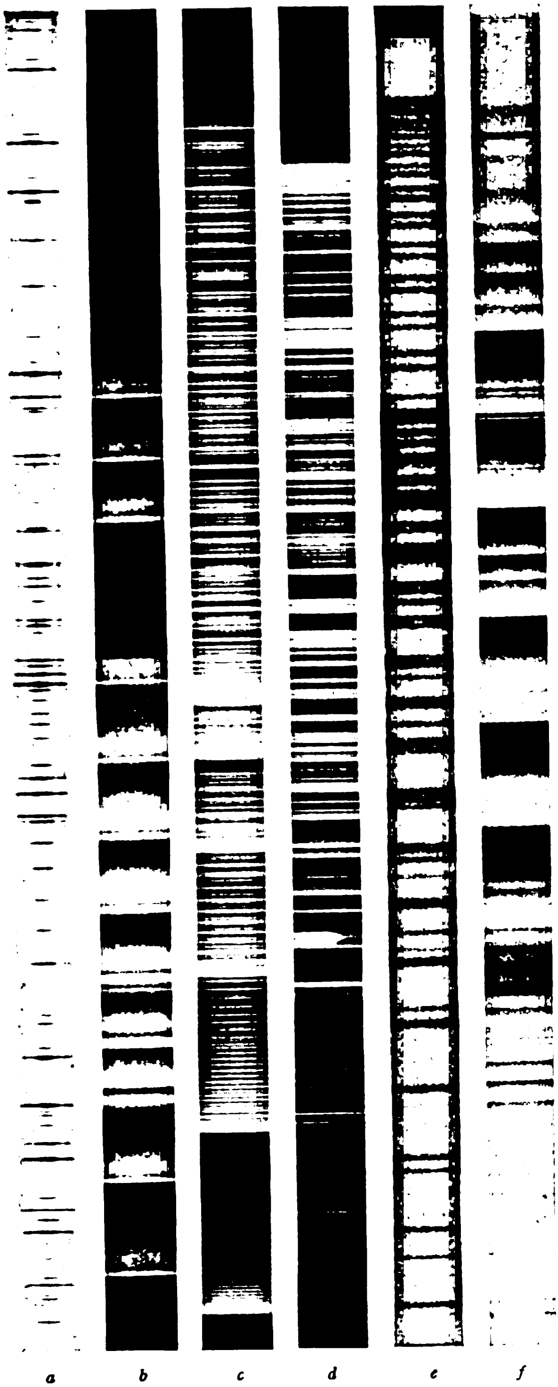
This figure is also adapted to the explanation of the mechanism of photochemical dissociation suggested a short time ago by Professor Franck of the University of Göttingen.* His suggestion is based on the fact that light quanta or photons are very light and move very rapidly. On account of their small momentum they cannot appreciably affect the momentum or kinetic energy of the heavy nuclei. Moreover they are apparently absorbed so quickly that the process is all over before the nuclei have moved any appreciable distance from their initial positions. The molecule can dissociate only if it receives an amount of nuclear vibrational energy greater than the energy of dissociation and it follows from the above considerations that the action of photons in producing dissociation must be *indirect*. Fig. 8 shows how it may be done. We suppose that the molecule is initially in the lowest electronic state A where it vibrates back and forth with a certain small initial vibrational energy. The impact of a light quantum (or of an electron) may now at any moment raise it straight upward to a point on one of the curves B or C. This

* Joint winner with Professor Gust. Hertz of the Nobel Prize for Physics for 1925.

change corresponds to a shift in the electronic energy with unaltered internuclear distance. The nuclear kinetic energy will be unchanged and the final energy will be approximately the sum of the initial kinetic energy and the final potential energy (or mutual electronic energy). Thus if caught at the point *a* it may be carried up to the point *b*, the initial and final kinetic energies being in this case zero. After absorption we have still a molecule, but the latter is left, so to speak, "on the side of a hill" and slides down past the equilibrium point and up over the opposite slope to return no more. In other words the repulsive force and mutual energy of the atoms at *b* is so great that they are torn apart despite their mutual attraction at large distances and separate with a residual kinetic energy marked "energy of escape" on the figure. This theory of optical dissociation fits the observed facts very well and seems to be one of the most important recent contributions from physics to photochemical theory.

In conclusion I should like to tell you a little something about the wave or quantum mechanics and the new light which it has shed on the problem of molecular structure. In the time available I can hope to give you only rather vague ideas, but perhaps they will be worth while. This new mechanics is, I think, more revolutionary than Einstein's doctrine of relativity. It certainly is more important from most points of view than that justly famous theory. The quantum mechanics was developed because the Bohr theory despite many initial successes proved on close examination inadequate to account fully for the experimental facts. It accounted approximately for the energy level schemes of atoms and molecules, but failed quantitatively in this domain of its greatest success besides failing completely to answer questions about refraction, collisions, and other aperiodic phenomena. To mention an important specific instance, the Bohr theory proved inadequate to account for the formation of non-ionic molecules. These molecules are apparently held together by some sort of pairing of valence electrons belonging to two atoms. The attempt to translate the static atom theories of Lewis and Langmuir into the dynamical language of Bohr leads to the assumption of valence electrons shared in such a way that they revolve in orbits either enclosing both

PLATE I.



a. Line spectrum of Argon (negative).
b. Silicon Nitride band system λ 4000 to λ 4800. Moderate dispersion spectrogram by Mulliken (positive).
c. λ 4216 group of violet CN band system. Spectrogram by Mulliken (positive).
d. High dispersion spectrogram of λ 6544 band of First Positive Nitrogen Group (N_2) by Birge (positive). [Report on Molecular Spectra, frontispiece (h)].
e. High dispersion spectrogram of λ 3040 band of the β system of NO. (Mulliken) (negative).
f. 'A' system of copper iodide bands. Moderate dispersion spectrogram by Mulliken (negative).

nuclei or located in a plane perpendicular to the molecular axis and midway between the nuclei. In either case the process of dissociation in the case of a symmetrical molecule would lead inevitably to a break at some point corresponding to a shift from shared orbits to unshared orbits. The study of the vibrational energy levels of symmetrical molecules shows no evidence for such a break, however, and it is highly improbable that anything of the sort exists.

Happily this difficulty along with many others disappears when we adopt the wave mechanics point of view. The fundamental thing about this new point of view as I see it is the recognition of the fact that the dual nature of light as both waves and corpuscles is a universal situation. Light apparently consists of bundles or corpuscles of energy which move as if guided from place to place by waves. To predict the behaviour of the corpuscles we must first solve a wave equation to see what the waves will do. Then the statistical behaviour of the corpuscles is to be determined by the fact that the corpuscular energy at any point is on the average equal to the intensity of the wave system at that point. We know nothing more than this statistical behaviour of the corpuscles. Now the recent experimental work of Davisson [5] and his collaborators shows that a beam of electrons is diffracted by a crystal in almost exactly the same way as a beam of X-rays, which are merely very short wave-length light rays. Thus electrons and presumably also protons and atoms have the characteristics of waves as well as of particles. Apparently all known kinds of particles are simultaneously waves and corpuscles. The essential difference between the electron and the photon lies in the differential equations of the two types of wave system. Thanks to de Broglie [6] and Schrödinger [7] we have found out how to set up the differential equation for electron waves and have discovered that it

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[5] Davisson and Kunsman, *Phys. Rev.*, **22**, 242 (1925); Davisson and Germer, *Phys. Rev.*, **30**, 705 (1927); C. J. Davisson, J. FRANKLIN INST., **205**, 597 (1928).

[6] L. de Broglie, *Annales de Physique* (10), **3**, 22 (1925).

[7] E. Schrödinger, *Annalen der Physik*, **79**, 361 and 489 (1926). *Phys. Rev.*, **28**, 1049 (1926). The statistical interpretation of Schrödinger's theory which lies behind the Dirac-Jordan transformation theory form of the quantum mechanics and the Heisenberg principle of indeterminateness was first stated by Born, *Zeits. f. Phys.*, **38**, 803 (1926).

yields results in agreement with ordinary mechanics for large scale phenomena though the results are different for atomic and molecular problems.

The attack on the problem of atomic mechanics now becomes essentially the same as the attack on a problem in the propagation of photons. We first set up the differential equation for the wave-phenomenon which parallels the corpuscular phenomenon (a physical analogue of psychophysical parallelism!). We solve this problem subject to certain boundary conditions and obtain first of all a set of discrete wave frequencies like the frequencies of vibration of a stretched string. These frequencies multiplied by Planck's constant give us the experimental energy level system of the atom or molecule. We also get a definite wave-system for each energy level whose intensity we believe determines the statistical behaviour of the electrons or other particles which make up the system. Concerning the finer details of the electronic motion we know as little as we know about the details of the motion of photons, i.e., exactly nothing.

Let me illustrate. The simplest atom is that of hydrogen, which consists of a single electron revolving about a heavy positive nucleus. Its energy level scheme was given correctly * by the Bohr theory and is given correctly by the wave mechanics. According to the former theory every energy level is associated with a definite type of circular or elliptic orbit. According to the new quantum mechanics it is associated with a system of standing waves having the nucleus as its center. In the case of the normal state the wave-system is spherically symmetric without nodes. In all cases it extends to infinity in all directions but drops off very rapidly in intensity outside a sphere of radius equal to the aphelion distance in the corresponding Bohr orbit. We interpret the infinite extent of the wave system to mean that the electron occasionally makes very long excursions from home, there being no limit to the length of these excursions.

Applied to the vibrational and rotational motion of a diatomic molecule the wave mechanics gives essentially the same energy levels as the Bohr theory and allows us to

* The fine structure is not quite right if the calculation is made on the basis of a model including an electron spin.

retain our previous interpretation of the spacing of these levels practically unchanged. The greatest success of the new theory, however, is in its application to the problem of molecule formation. There is no longer any difficulty about the breaking of orbits due to the separation of the atoms in a non-ionic molecule, for the fragile glass-like orbits of the Bohr theory are replaced by the plastic solutions of a partial differential equation. Consider the hydrogen case which has been studied in some detail. If two normal hydrogen atoms approach each other their wave-systems overlap and an interference phenomenon is set up much like the interference of light from two apertures in Young's experiment. This interference between the wave-systems alters the vibration frequency and energy in a way which varies with the distance between the nuclei and gives us a mutual energy curve in essential agreement with that which the band spectrum of hydrogen has revealed.[8] The results (see table) are not perfect since the solution of the wave equation is a difficult mathematical problem for which we have as yet but a first approximation. The agreement is satisfactory, however, in view of the approximations involved and taken with the many other successes of the theory warrants us in regarding the problem of the formation of the hydrogen molecule as solved in principle. We have every expectation that these results are capable of being generalized to apply to other types of molecule. Apparently the pairing of valence electrons noted so long ago by the chemists is an interference phenomenon.

TABLE OF CONSTANTS FOR NORMAL HYDROGEN MOLECULE.

	r_0 (10^{-8} cm.).	D (volts).	ν_0 (cm.$^{-1}$).
Computed (Sugiura)	0.80	3.2	4800
Computed (Wang)	0.74	3.8	4900
Observed	0.75	4.4	4360

ν_0 denotes the vibrational frequency for an infinitesimal amplitude in wave-number units.

[8] Heitler and London, *Zeits. f. Phys.*, **44**, 455 (1927); Sugiura, *Zeits. f. Phys.*, **45**, 484 (1927); S. C. Wang, *Phys. Rev.*, **31**, 579, 1928.

PROBE MEASUREMENTS IN THE NORMAL ELECTRIC ARC.

BY

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Foundation
Communication No. 25.

Abstract. Probe measurements have been made in cadmium, thallium and carbon arcs by sweeping the probe through the arc at a constant velocity and measuring the current collected by the throw on a ballistic galvanometer with different probe potentials applied. The voltage-current characteristic was analyzed to get a measure of the positive ion concentration, the average electron temperature and the space potential by the Langmuir method. The cathode falls found were each equal to, or only slightly higher than, the ionization potential of the active gas, and were 9.0 volts in the cadmium arc, 6.5 volts in the thallium arc and 5.0 volts in the carbon arc. The last value is to be compared with the ionization potential of the cyanogen molecule of 4.4 volts. The anode fall found in the carbon arc was 16.5 volts. These values for the carbon arc agree almost exactly with the "forward" and "back" E.M.F.s measured by Duddell and others at the cathode and the anode but not identified by them as the cathode and anode falls. The electron velocities were found to be Maxwellian with average velocities sufficiently high to account for the ionization known to exist. Over parts of the arc stream where the fields were found to be large the electrons showed corresponding increases in average temperature and evidence that only about three-quarters of the energy gained by the electrons from the field between collisions is lost by the lectrons while the remaining quarter is retained and made evident by the steady increase in the electron temperture. As the current flowing through the arc was increased, the radiation per unit volume and also the positive ion current per unit length of the probe were found to increase very rapidly indicating an increase in the efficiency of the ionization process as the current increases. It is thought that this observation is closely related to the fact that the voltage drop across the arc decreases as the arc current increases.

THE Langmuir probe method of determining the electronic energy distribution and the positive ion concentration in low pressure arc discharges, has been used to explore certain normal arcs operating at atmospheric pressure. The new facts concerning the detailed mechanism of the electric arc which were revealed by these probe measurements seem to be of sufficient importance to warrant this advance report being made before the entire project has been completed. More extensive explorations of a number of different arcs are now being prepared, the results of which will also be published in this JOURNAL.

THE LANGMUIR PROBE METHOD.

The theory of the use of probes for measuring space potentials, electron energies, etc., has been presented in a series of papers by Langmuir and Mott-Smith [1] along with examples of experimental results. Although the details of procedure were a little different in the case at hand, the general method was the same as that developed by the above writers and can be outlined as follows.

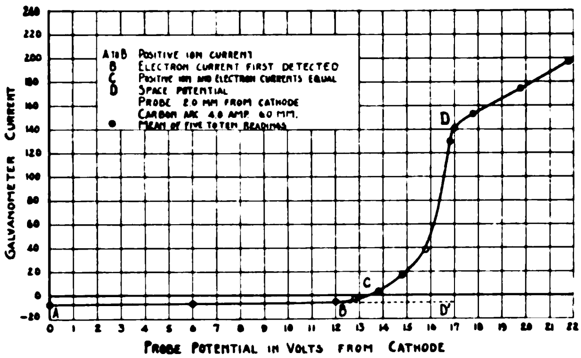
The direct current arc is usually operated by power furnished the electrodes from a battery or generator through a suitable resistance which stabilizes the discharge at the preassigned current flow. The potential drop over the arc, measured at the electrodes, is usually thought of as being divided into three parts, namely, (1) the cathode fall very close to the negative electrode surface, (2) the arc stream fall in potential supposedly distributed uniformly along the arc stream, and (3) the anode fall at the surface of the positive electrode. Thus the potential of the space at any given distance from one of the electrodes, for instance, the cathode, is made up of the cathode fall plus that part of the arc stream fall between the point in question and the cathode. In order to measure this space potential it is not sufficient simply to immerse the probe in the discharge and measure its potential by means of an electrometer or a high resistance voltmeter. The result can only be gotten in the more indirect way of studying the voltage-current characteristic of the probe when it is immersed in the discharge and maintained at definite potentials with respect to one of the electrodes by means of a battery. The potential of the cathode will be taken arbitrarily as zero and a current of positive charges coming to the probe will be called a negative current in order to be consistent with the accepted practice. If the probe potential is negative with respect to the space, a positive ion sheath will form around the probe. Within this sheath perfect reflection will take place of all the electrons which enter it with insufficient velocity to penetrate to the probe against the adverse field set up, due to the charge maintained on the probe by the battery. Positive ions which happen to enter the sheath find themselves in a field of force which carries them through the

[1] *G. E. Rev.*, **27**, 449, 538, 616, 762, 810 (1924).

sheath to the probe and the rate at which these ions come to the probe is indicated by the current flowing in the probe circuit.

This positive ion current, AB of Fig. 1, is seen to change very little as the probe potential changes. What change there is observed is due to the change in the surface area of the sheath as the probe potential is altered. When the probe is slightly negative with respect to the space, enough fast electrons are able to penetrate the sheath and strike the probe to give an electron current large enough to be measured, superimposed on the positive ion current. This point is indicated by B in Fig. 1. At C on the same curve, the electron

FIG. 1.



Voltage-current characteristic of probe in carbon arc.

current exactly equals the positive ion current making the total current registered in the probe circuit zero, and thus showing the potential which would be found if the probe were connected to a high resistance voltmeter and allowed to "float." At potentials higher than C the electron current exceeds the positive ion current. If it happens that the electrons which come to the probe have a Maxwellian distribution of velocities, a plot of the ordinates representing the difference between the curves BCD and BD' on semi-logarithmic paper will give the average temperature of the electrons because of the well known relationship

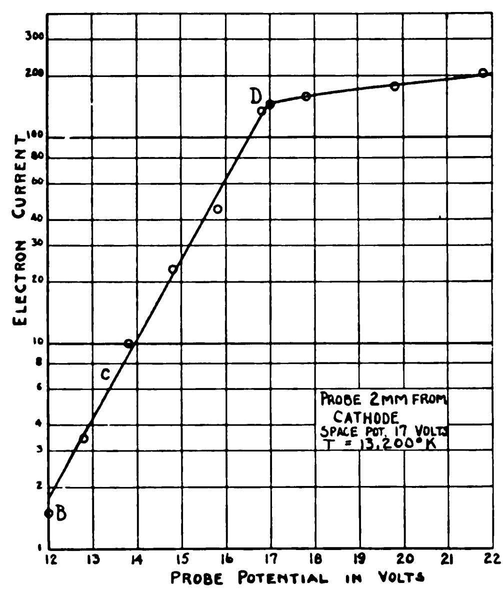
$$i = a\epsilon^{\frac{eV}{kT}} \qquad (1)$$

which applies to this case. Since

$$\log_e i = \frac{e}{kT} V + \log_e a, \tag{2}$$

the slope of the straight line part of the curve *BCD* of Fig. 2 must be e/kT and with e/k known ($e = 4.774 \times 10^{-10}$ e.s.u. and $k = 1.372 \times 10^{-16}$ ergs per degree) the temperature T can be calculated. The theory of the Langmuir probe method predicts that the "current-voltage" characteristic will show

FIG. 2.



Semi-logarithmic plot of electron current.

a change in slope when the probe potential equals the space potential. It is on this basis that the bend of the curve at *D* in Fig. 2 is taken as an indication of the true potential of the space.

Probe measurements following the general method described above have been successfully carried out in low pressure discharges with the probe continually immersed in the discharge space. Such a procedure is not possible in the high pressure arc because the bombardment of the probe is so

violent that it soon heats up to the melting point or else it becomes hot enough to give off electrons in sufficient number to invalidate the results. The method adopted, therefore, has been to swing the probe by a mechanical means at practically a constant velocity, through the discharge so rapidly that it does not heat up sufficiently to cause trouble. The potential was maintained on the probe by means of a low resistance battery and the current measured by the throw of a ballastic galvanometer properly shunted. To use the measurements to indicate the space potential and the average energy of the electrons, it is not necessary to know the area of the arc stream swept over by the probe but in order to compare the positive ion currents collected at various parts of the arc or in arcs with different currents flowing, it is necessary to know the area swept out. Photographic measurements of the light given off by the arc show that the conditions in the arc over any plane perpendicular to the axis of the arc can be considered to be uniform. It is possible to show that if a probe is moved through the arc at a uniform velocity v, the quantity of current Q which flows through the galvanometer circuit is

$$Q = \frac{\pi r^2 i}{v}, \tag{3}$$

where r = radius of the arc where the probe swings through, and i = the current per unit length of the probe, and depends on the condition of the gas within the arc.

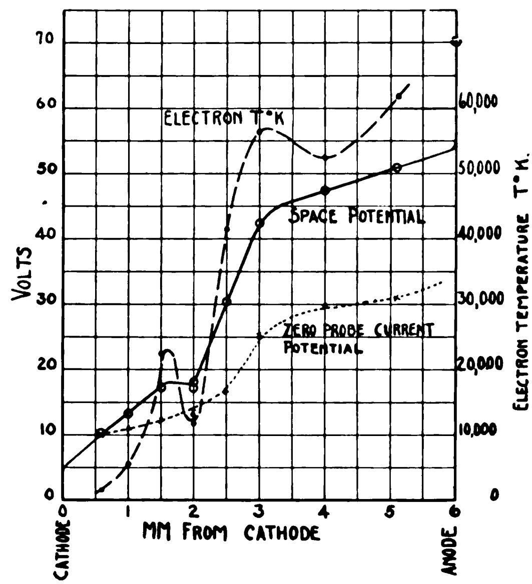
RESULTS OF MEASUREMENTS.

The arc materials studied so far have been (1) cadmium in argon, (2) thallium in argon, and (3) carbon in air.

Cadmium Arc.—The results of the measurements on the cadmium arc in argon at atmospheric pressure showed that the cathode fall was exactly equal to, or very slightly greater than, the ionization potential of cadmium which is 8.9 volts and that the anode fall was of the order of one volt. The field along the arc stream was uniform and about one volt per millimeter. These measurements were made on 4 mm. arcs carrying currents of 1 to 4 amperes. The average energy of the electrons half way between the electrodes increased

slightly as the current was increased. The electron temperatures found were 5400° K. for 1.0 and 2.0 amperes, and 6100° K. for 4.0 amperes. The average electron energies corresponding to these temperatures expressed in equivalent volts are 0.7 and 0.79 volt respectively. A tungsten probe 0.2 mm. diameter was used.

Fig. 3.



Distribution of potential and electronic temperature along the carbon arc.

Thallium Arc.—Measurements of a 2.0 ampere 4 mm. thallium arc in argon showed also that the cathode fall was exactly equal to or slightly higher than the ionization potential of thallium of 6.08 volts. The field along the arc stream in this case was about 1.5 volts per mm. and the average temperature of the electrons 7750° K. which is the equivalent of 1.0 volt. Whether or not this average energy of 1.0 volt is in any way related to the known metastable electron level of 0.96 volt for the thallium atom, is a point we hope to settle by further measurement.

Carbon Arc.—The results obtained on the carbon arc have proved to be by far the most unexpected. The carbons

studied were furnished by Gebrüder Siemens & Co., Berlin, and classified by them as "+ E + HOMOGENKOHLE + E +." Spectroscopically these were found to be the purest of all of the carbons tried out preliminary to the beginning of this study. A very faint trace of sodium was found to be present along the entire length of the arc stream and a trace of iron impurity showed in the spectrum in the immediate neighborhood of the cathode. Since it has been impossible to obtain carbons of greater purity than these, we have not been able to prove that the irregularities in the carbon arc stream disclosed both by the photographs and the probe measurements, are really inherent in the carbon arc or were found in this case as a result of the traces of impurities. A carbon probe burned to 0.4 mm. in dia. was used for the measurements.

The curves on Fig. 3 serve to illustrate the general results so far obtained with the carbon arc. The solid line (heavy over the range of measurement, light in extrapolation) shows the distribution of potential along the arc from the cathode taken as zero to the anode at 70.5 volts, a result in good agreement with the Ayrton [2] value of 69.6 for pure carbons. A straight line extrapolation of the line through the observed points from 0.6 to 1.5 mm. from the cathode gives a cathode fall of about 5.0 volts which is lower than that given by other observers.[3, 4] This value agrees with the estimated value, 4.4 volts, of the ionization potential of the cyanogen molecule given by Mullikan [5] and extends the general observation mentioned above that the cathode fall is equal to or slightly greater than the ionization potential of the gas actively involved. Between 1.5 mm. and 2.0 mm. from the cathode there was no increase in potential while over the range 2.0 mm. to 3.0 mm. the potential increased 25.0 volts. From this point on no irregularities were found. The field of 40 volts per cm. agrees with that found by Hagenbach and Wehrli.

The anode fall of 16.5 volts is lower than that measured by

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[2] Ayrton, "The Electric Arc," p. 185.

[3] Ayrton, "The Electric Arc," p. 218. Cathode fall 11.0 volts.

[4] Hagenbach and Wehrli, *ZS. f. Phy.* **26**, 23 (1924). Cathode fall 7.1 volts.

[5] *Phys. Rev.*, **25**, 291 (1924).

Ayrton [6] (34.0 volts) and that calculated by Hagenbach and Wehrli [4] (33.7 volts).

It is interesting to note that the values for the cathode and the anode falls as found by the Langmuir probe exploration coincide almost exactly with the "forward" and the "back" E.M.F. measurements of the cathode and the anode spaces published by Duddell [7] in 1904 and by Hagenbach and Wehrli [4] in 1924. In both cases small intensity high frequency currents, 100 and 190 kilocycles, were used and determinations of an apparent E.M.F. and an IR drop from the probe to the electrode were made. The cathode E.M.F. was found by Duddell to be − 5 to − 6 volts and Hagenbach found − 6.1 volts. The anode E.M.F. was measured as 15 to 17 volts by the former and as 16.7 volts by the latter. The numerical values agree almost perfectly with those now found by the Langmuir probe method to be the true cathode and anode falls.

The measured electron temperatures showed an interesting relationship to the electric fields accelerating the electrons. At the termination of each rise in voltage, namely at 1.5 mm. and 3 mm. there was a maximum temperature of the electrons, and immediately following, over the range of smaller field the electron temperature dropped. This drop was particularly noticeable at 2.0 mm. from the cathode. At the maximum at 1.5 mm. from the cathode, the average energy of the electrons expressed in equivalent volts was about 3.0 volts, thus allowing for many electrons with sufficient energy to ionize the CN molecule in a single impact. Over the entire range from 2.5 mm. on, the electrons on the average had acquired sufficient energy to ionize the CN molecule easily. Thus it can be said that it is an experimental fact that the electrons have acquired sufficient energy from the field to produce the ionization required for the maintenance of the electric arc in spite of the fact that the fields are small. This observation should make it unnecessary to invoke the indirect explanation based on Saha's equation as given by Compton [8] to explain the ionization known to exist.

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[6] Ayrton, "The Electric Arc," p. 215.

[7] *Phil. Tran.*, **203**, 305 (1904).

[8] *Phys. Rev.*, **21**, 286 (1923).

The consistency with which the electron temperature rises while traversing a region of the arc where the field is high suggests that the electrons gain their high temperatures by their acceleration in the field. We shall assume that electrons after collision with molecules come off with a Maxwellian distribution of velocities and that they communicate on the average a fraction α of the energy which they have gained from the field since the last impact. If, under these conditions, X is the field, u the average velocity of the electrons along the axis of the arc, e the electronic charge, and n the number of electrons per c.c., the energy converted into heat per second will be $neuX$. The amount which goes into temperature energy of the electrons, is according to the above hypothesis $(1 - \alpha)neuX$. Thus if T is the temperature of a group of electrons whose motion we follow

$$(1 - \alpha)neuX = \frac{3}{2}kn\frac{dT}{dt} = \frac{3}{2}kn\frac{dT}{dx}u, \tag{4}$$

where k is the molecular gas constant. On integration between two points along the arc we find

$$(T_2 - T_1) = (1 - \alpha)\frac{2e(V_2 - V_1)}{3k}. \tag{5}$$

We can convert an electron energy corresponding to a given temperature T into equivalent volts v by taking

$$v = \frac{3}{2}\frac{k}{e}300T$$

$$= 1.293 \times 10^{-4}T. \tag{6}$$

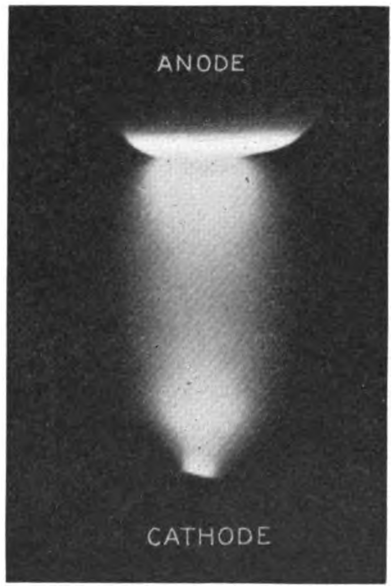
Solving equation (5) we get

$$(1 - \alpha) = \frac{v_2 - v_1}{V_2 - V_1}. \tag{7}$$

The application of this result to the range 2.0 mm. to 3 mm. in Fig. 3 gives $\alpha = 0.78$ while over the range from the cathode fall to 1.5 mm. we get $\alpha = 0.763$. This seems to show that electrons moving along the arc under the influence of the field lose on the average only about three-quarters of the energy gained over their free paths by impact on molecules.

In order to illustrate the error involved in probe measurements, before the Langmuir analysis was proposed, the points showing the probe potentials for which no current flowed to the probe are plotted along the dotted line in Fig. 3. It is easy to see how the irregularities which have been observed above were not detected.

Fig. 4.



Photograph of 4.0 amp., 6 mm. carbon arc.
Light from 4216 Å cyanogen band.

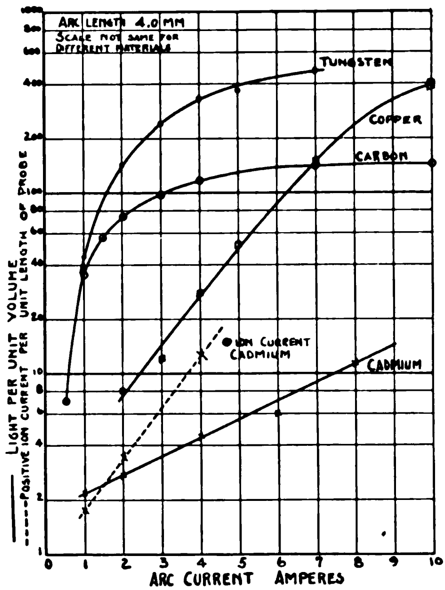
Figure 4 is a reproduction of a photograph taken of an arc 6 mm. long carrying 4 amperes which shows quite clearly the fact that maxima and minima in the light given off the arc stream follow exactly at the points of irregularity as shown by the probe. In particular the maximum of light intensity at 1.5 mm. from the cathode has a direct counterpart in the potential curve of Fig. 3 because at this point there is a marked change in slope in the direction to indicate a region of positive space charge, and therefore, a region of high positive ion concentration.

CORRELATION BETWEEN POSITIVE ION MEASUREMENTS AND LIGHT INTENSITIES.

Probe measurements in the cadmium arc showed that the positive ion current *per unit length* of the probe increased very rapidly with an increase in the current flowing in the arc although the current density over any cross section of the arc has been found to be constant and independent of the current. This observation seems to indicate an apparent increase in the efficiency of the ionization process as the current is increased. Such an increase in efficiency might conceivably be brought about because the volume occupied by the arc stream is directly proportional to the current flowing. The larger volume results in a greater radiation flux and absorption of the resonance radiation in each element of volume and thus increases the efficiency. It is perhaps along these lines that we must look for an explanation of the fact that the voltage drop across the arc decreases as the current flowing increases. Selected radiation, not including resonance radiation, has been found to be emitted without appreciable absorption in passing through the arc. A photoelectric cell has been set up with an appropriate lens system to measure the radiation of a selected wave-length (or range of wave-lengths) which comes from a little cylinder of the arc stream formed by passing two planes perpendicular to the axis of the arc and including 0.5 mm. of the arc stream's length. From previous measurements it is known that the light per unit volume is uniform over such a cylinder and therefore if the total light recorded by the cell is divided by the known area, the light per unit volume will be known and this can be compared with the positive ion current per unit length of the probe. The light intensity measurements showed the same type of rapid increase of intensity per unit volume when the arc current was increased as was found for the positive ion current. Copper, carbon and tungsten arcs also were measured and found to show a great increase in light per unit volume as the current increases. The carbon and the tungsten arcs showed a marked tendency for the light per unit volume to reach a "saturation" value. In view of the fact that the areas of cross section of these arcs are greater than the others measured, a more rapid approach of the emitted

radiation to a saturation value with increasing current is to be expected because of the larger absorption of the light in the arc itself. The curves shown in Fig. 5 serve to illustrate the rapid increase in positive ion current and light per unit volume and also the tendency towards light saturation in the carbon and tungsten arcs.

FIG. 5.



Light intensity and positive ion measurements.

Qualitatively, this increase in radiation has been known by the medical profession for some time and measurements of A.C. arcs between impregnated electrodes summing the radiation along the axis of the arc instead of at right angles to its axis, have been published by Coblentz,[9] Dorcas and Hughes. Their results are qualitatively much the same as the writer's, showing a tendency to saturate at slightly higher currents, although they did not express their results in such a way as to make this point obvious.

It is apparent from the results presented that the use of

[9] Sci Papers of Bureau of Standards No. 539, Nov. 19, 1926.

the Langmuir probe and the correlation of the probe measurements with other physical measurements of the arcs, such as light intensity, ionization potential, etc., opens a whole new field of research, the outcome of which promises to fill in many details of the mechanism of the electric arc which have evaded discovery for a long time.

To Professors W. F. G. Swann and K. T. Compton, I am greatly indebted for many valuable suggestions.

The Liter and the Cubic Decimeter. H. W. BEARCE. (*Science*, May 18, 1928.) In the establishing of the metric system it was intended to derive the units of length, area, volume and mass from the meter which was to be the ten-millionth part of the length of the earth's quadrant from pole to equator. A cube a tenth of a meter on a side was the unit of volume and the mass of this volume of water at its maximum density was the kilogram. Difficulties were encountered in making these plans concrete. It was a task beset by serious obstacles to measure accurately a quadrant of the earth and the meter was later defined by reference to a definite material standard. Furthermore masses could be compared with greater accuracy than was obtainable by deriving a mass from volume measurements, so that the kilogram also was defined by reference to a concrete standard. An additional step was taken by defining the liter as the volume of a kilogram of water at maximum density. The liter as thus defined is 27 parts in a million larger than the cubic decimeter specified by reference to the earth's quadrant, and the milliliter is in the same proportion larger than the cubic centimeter.

The author, who is in the Bureau of Standards, regrets this existing confusion in units and decries the use of 'cubic centimeter' in measuring the volume and density of liquids instead of the correct 'milliliter' (ml.). For the abbreviation of 'cubic centimeter' he prefers 'cm^3' to 'cc.'

G. F. S.

A CONSIDERATION OF TUNGSTEN-FILAMENT LAMPS IN RADIATION THERAPY.

BY

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FOR many years science has been investigating the physiological effects of radiant energy with the result that some definite knowledge is now available. However, almost every question that is asked pertaining to some phase of radiation therapy is wholly unanswerable, or incompletely answerable at best. Seldom does the public "keep up with science" but occasionally it "gets ahead of knowledge." People have knowingly or unknowingly practiced radiation therapy with solar energy since the dawn of savagery. Notwithstanding all this, the entire field is still in the "twilight zone of knowledge." Combining this with the natural desire to grasp at any promising boon to life and to health we have a situation which is fraught with some dangers and many difficulties.

There are uncounted photochemical reactions. Doubtless radiant energy of all wave-lengths in the ultraviolet region plays many parts in chemical processes. It is possible that radiant energy of all these wave-lengths may eventually be used in some manner to benefit the life and the health of human beings. However, we are far from a complete knowledge of these possibilities. Interest in ultraviolet therapy at present is chiefly concentrated in the spectral region between the wave-length limits from 3200 A and 2800 A. Ultraviolet energy of other wave-lengths produces many effects and, therefore, has or will have many practical applications. However, for such purposes as the prevention and cure of rickets, radiations of shorter wave-lengths than 3200 A seem to be the most effective. There are some indications that radiant energy of shorter wave-length than 2800 A, or thereabouts, may be harmful, at least in overdoses. In the absence of complete knowledge it is prudent to avoid the use of radiant

energy in therapy of shorter wave-lengths than 2800 A. This has an attractive philosophical basis, inasmuch as these radiations shorter than λ 2800 do not reach the earth from the sun and, therefore, human beings are not adapted to them or may not have developed the means of using them beneficially. However, this does not mean that they may not be useful, for Roentgen and radium rays have many uses in preserving life and health even though human beings have not been exposed to appreciable amounts in their natural environment.

With the great and increasing interest in ultraviolet radiation, the light-sources in common use are turned to for possible assistance. The sincere and cautious therapist can safely apply any of the special sources of radiant energy, but upon looking toward a possible general use by the public other considerations are important. With tungsten-filament lamps in such prevalent use for lighting purposes the possibilities of their use in ultraviolet therapy receive much attention by the public as well as by physiologists, physicians, and others. The final proof of their efficacy in such a field must await the results of researches, but physical analyses of the radiations throw some light upon the desirability of such researches. There has been a tendency on the part of some to discard this source of radiation without a trial. However, in the present state of scanty knowledge this attitude is unscientific. Obviously, tungsten-filament lamps cannot compete in quantity of ultraviolet energy with solar radiation, with that from the quartz mercury arc, or with other arcs. However, it is legitimate to inquire whether or not the small amount of ultraviolet energy emitted by tungsten filaments, working over long periods of time such as the hours of ordinary illumination in work-places and elsewhere, may not be beneficial. Many persons are exposed to very little sunlight or even skylight for many months in the year. Aside from the relatively feeble skylight which enters our homes, offices and other work-places many of us are exposed no more than a few minutes per day to solar radiation. What is the minimum exposure to ultraviolet energy—both in time and in intensity—that human beings require? These and many other questions remain unanswered.

For many years it has been known that ordinary glass does not efficiently transmit radiant energy shorter than λ 3200. This is true of the ordinary bulbs of tungsten-filament lamps. For this reason it is of interest to learn whether or not it appears worthwhile to equip present filament lamps with special bulbs or to conduct therapeutic researches with them. Measurements of small amounts of ultraviolet energy in definite spectral regions are fraught with many difficulties. In the case of the sun the quantity of ultraviolet energy varies enormously with the sun's altitude, with the composition of the atmosphere, with cloudiness, etc. Incidentally, it is not commonly recognized that light from a clear blue sky is rich in ultraviolet.

Although we have made many measurements of ultraviolet content, both spectrally and with selective filters of rather indefinite cut-offs, the writer prefers to present here the results of computations. This is done with a full knowledge of the limitations of the data, particularly on account of the questions which arise as to the applicability of radiation laws to the ultraviolet. However, inasmuch as we are only interested in this preliminary survey in the order of magnitude of the quantities, the computational method of approach seems satisfactory. In regard to the content of ultraviolet energy between the limits of λ 3200 and λ 2800 in solar radiation at the earth's surface, we shall use a value which in our judgment is satisfactory for the purpose as arrived at from various sources of data and experience. We have chosen the value of two per cent. of the total solar radiation reaching the earth's surface. Perhaps this represents more nearly an average of the maximal content rather than an average. Certainly, throughout many hours of many days and throughout many months, excepting in desert regions of low latitudes, this value is high. However, if this figure is not agreeable to others the data presented herewith may readily be revised. It seems likely that it represents the order of magnitude throughout several hours during the middle of the day on sunny days in summer. The data for the radiation emitted by the quartz mercury arc and solar radiation are based upon measurements. As already stated, the data for the radiation from tungsten filaments are computed and it is assumed that

the bulb is perfectly transparent to the ultraviolet radiations under consideration.

On the basis of equal total energy from various sources of radiant energy the percentages of the total energy throughout the entire spectrum represented by the energy between λ 3200 and λ 2800 are found to be as given in Table I in the column indicated as "Percentages." For ease of comparison relative values are also given in terms of ultraviolet radiation between λ 3200 and λ 2800 taken as unity. The first three sources are filament lamps operating at color-temperatures 2920° K., 3180° K. and 3220° K., respectively.

TABLE I.

	Percentages	Relative
500-watt tungsten lamp designed for 1000-hr. life	0.018	0.009
500-watt tungsten lamp designed for 100-hr. life	0.047	0.024
900-watt tungsten "movie" lamp at 100-hr. life	0.054	0.027
Solar radiation at noon on a clear day	2.000	1.000
450-watt quartz mercury arc	3.150	1.575

Thus it is seen that the ultraviolet energy under consideration is relatively small in amount from tungsten-filament lamps compared with that in equal quantities of solar radiation or of the energy emitted by the quartz mercury arc. In the case of the filament lamps it is of the order of magnitude of one hundredth of that in equal amounts of total energy from the other two sources. However, this is not completely discouraging until the questions already asked—and others—are completely answered by researches.

Now let us compare these on the basis of equal lumens or equal quantities of visible light—that is, on the basis of equal intensities of illumination from the ordinary lighting viewpoint. This is done in Table II. For this transformation the values of lumens per watt as used for the five sources are respectively 19.2, 25.8, 27.3, 100, and 50. By dividing the values in Table I in the column indicated by "Percentages" the watts (radiated between the limits λ 3200 and λ 2800) per lumen are obtained. These values are omitted but for ease in comparison are presented in Table II relative to this energy in solar radiation.

TABLE II.

500-watt tungsten-filament lamp designed for 1000-hr. life	0.05
500-watt tungsten-filament lamp designed for 100-hr. life	0.09
900-watt tungsten "movie" lamp designed for 100-hr. life	0.10
Solar radiation at noon on a clear day	1.00
450-watt quartz mercury arc	3.10

On the basis of ultraviolet energy (of restricted wavelengths) per lumen the case appears more promising for the tungsten-filament lamp until we reflect that solar radiation is so intense that the visible light is measured in thousands of foot-candles reaching a maximum occasionally in the neighborhood of 9000 foot-candles. In artificial lighting with ordinary sources we commonly use only a few foot-candles although the level of illumination is rapidly increasing. However, in the present state of the lighting art an intensity of 20 foot-candles is commonly considered high. Economic and other considerations will eventually push this to much higher intensities, but excepting in special cases such as the motion-picture production-studios, searchlight uses, etc., we do not yet see the age of 1000 foot-candles of artificial light for work-places in sight.

Let us assume for a moment that physiological effects of radiant energy are directly proportional to the product of time of exposure and the quantity of ultraviolet energy. This relationship is not necessarily true over wide ranges. Certainly it does not hold in some other uses of radiant energy and is by no means a universal law. However, assuming for the moment it is true, the same therapeutic result would be obtained in a given time of exposure to 100,000 foot-candles from an ordinary 500-watt tungsten-filament lamp (with a special bulb) as from 5000 foot-candles of solar radiation at noon on a clear day. Such an intensity of illumination from tungsten-filament lamps is wholly impracticable. With the same assumption as in the foregoing, the same therapeutic result would be obtained in 5000 minutes' (83 hours') exposure to 20 foot-candles from the ordinary tungsten-filament lamp (with a special bulb) as from a one-minute exposure to 5000 foot-candles of noon sunlight. If the 500-watt lamp operated at a temperature which reduced its life to 100 hours the foregoing time of exposure would be reduced to one-half, provided the assumption made is tenable.

However, is the assumption tenable? Our eyes, for example, utilize a small quantity of light much more efficiently per unit of light than they utilize a great quantity per unit of light. It is possible that our skin or its receptors of radiant energy may do likewise. To receive the benefits of ultraviolet radiation while working at regular tasks requires that the face and hands in general are sufficient as receiving-stations. In the light of present knowledge this seems quite likely.

The data are presented for what they may be worth. The facts are to the writer at once discouraging and encouraging. Small amounts of ultraviolet energy known to be beneficial are emitted by tungsten filaments. These may be appreciably augmented by increasing the filament temperature. Will researches show that these small quantities operating for long periods, such as all of us spend under artificial lighting markedly benefit us? Researches in this direction will be tedious and time-consuming. However, the evidence revealed by such computations as presented herewith are not wholly discouraging to the contemplation of researches which will answer the many questions which may arise.

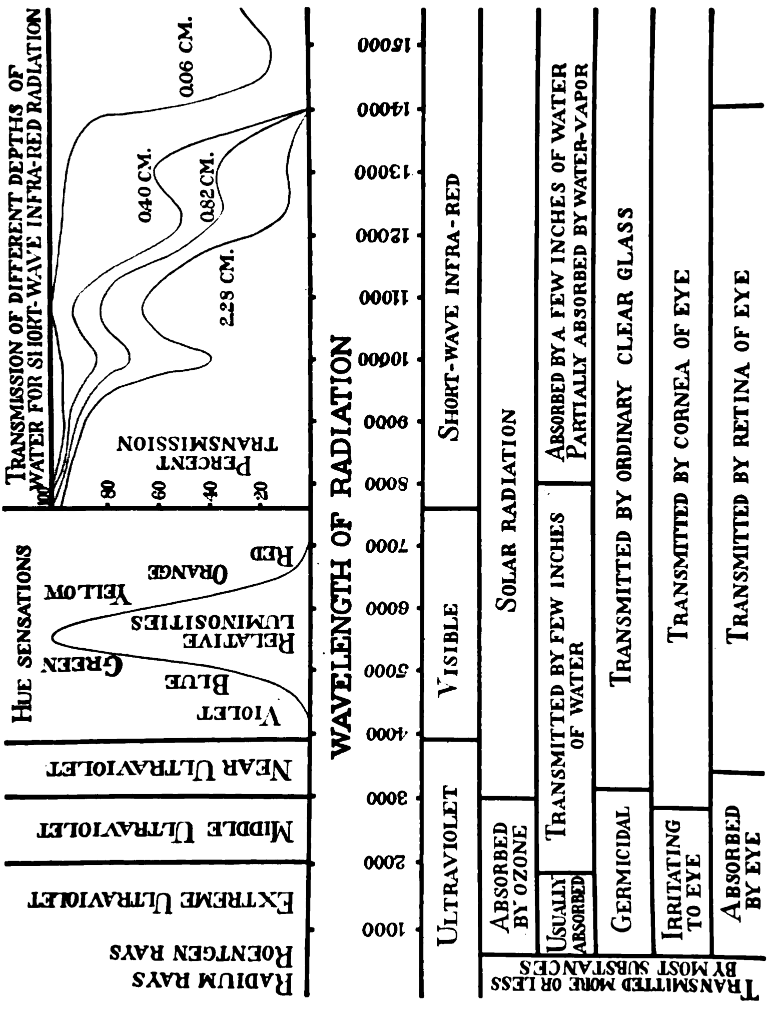
In the foregoing discussion radiation therapy has been discussed within very narrow limits. As knowledge increases there are good reasons for believing that the wave-length limits of beneficial radiation will be greatly extended.[1] If ultraviolet energy of wave-lengths greater than λ 3200 is found to have therapeutic value, the use of tungsten-filament lamps will be more encouraging than the foregoing computations indicate. It is now known that germicidal action [2] extends to considerably longer wave-lengths than λ 3200.

There is a branch of therapy which relies upon heating effect with the attendant reactions such as hyperæmia. Hot towels and heating-pads are commonly known to be efficacious. They heat the body by conduction. Holding an electric filament lamp near the body can produce the same result with greater comfort to the person being treated. All the heating effect, excepting the small amount by conduction

[1] "Light and Health," by M. Luckiesh and A. J. Pacini, Williams and Wilkins Co., 1926.

[2] "Ultraviolet Radiation," by M. Luckiesh, D. Van Nostrand Co., 1922.

FIG. 1.



A diagrammatic presentation of certain data pertaining to radiant energy. (This diagram is taken from Light and Work by M. Luckiesh, D. Van Nostrand Co., 1924.) The wave-length scale is in angstrom units.

from the heated air, is achieved by the absorption of radiant energy. All kinds of lamps and bulbs have been devised and used for this purpose but in the light of present knowledge an ordinary tungsten-filament lamp seems to be best for this purpose. The body consists largely of water. It has been shown [3] that the percentage of incident energy absorbed by the first inch of clear water is 88 per cent. in the case of the treated carbon-filament and is less than 80 per cent. for the tungsten-filament vacuum lamp. For the gas-filled tungsten-filament lamp the percentage is still less. Thus it is seen that radiant energy from tungsten-filament lamps penetrates more deeply into water than that from carbon filaments. The color of flesh is red owing to the blood. From a consideration of the chart [4] presented in Fig. 1 and of spectral characteristics of blood and of these illuminants approximately the same conclusions are arrived at for the blood. Furthermore, where heating at a depth is desired in therapy the knowledge which we possess at the present time does not lead us to a preference for colored lamps unless perhaps red light is used where the greatest heating at a depth is desired with a minimum heating of the flesh near the surface. However, it does not seem that such a procedure is efficient and perhaps is seldom desirable. Using the total energy from an ordinary tungsten-filament lamp the heating at a depth would be the result of the penetration of some energy to the maximum depth, before it is converted into heat, and the conduction of heat from the layers of flesh near the surface to those deeper in the body. With such facts of physics understood the therapist will be guided not only in his researches but in his practice.

[3] "Radiant Energy and the Eye," by M. Luckiesh, *American Journal of Physiological Optics*, 2, Jan. 1921, p. 3.

[4] "Light and Work," by M. Luckiesh, D. Van Nostrand Co., 1924.

THE FERMI-DIRAC HYPOTHESIS OF GAS DEGENERATION AND ITS APPLICATIONS.

BY

E. S. BIELER, Ph.D.

1. INTRODUCTION.

ABOUT three years ago, the German mathematical physicist Pauli [1] gave a very remarkable explanation of the distribution of the electrons in an atom among the possible energy levels in terms of a principle which has been termed the Pauli exclusion principle.

"In any given atom there cannot be two electrons possessing the same combination of the four quantum numbers."

This afforded a logical if somewhat formal reason for the distribution first proposed by Stoner,[2] and amply supported by him on experimental grounds, of the electrons in an atom among the possible levels. In particular, it gave a very striking explanation of the occurrence of 2, 8, 8, 18, 18 and 32 elements in the five successive complete periods of the Periodic Table. Some of the consequences of the application of this principle, especially to the explanation of diamagnetism have already been reviewed in this JOURNAL.[3]

Shortly after this, Fermi [4] in Italy conceived the idea that Pauli's principle might be extended to apply to the molecules in a mass of gas, and thus afford a basis for the explanation of a number of properties of gases at low temperatures. Almost at the same time, Dirac [5] reached the same conclusion on the basis of a similarity between the expression of the properties of molecules and of electrons in Matrix Mechanics.

The list of important phenomena which have already received an explanation on the basis of this extension of Pauli's principle seems already imposing enough to warrant

[1] Pauli, *Zs. f. Phys.*, **31**, 765 (1925).

[2] Stoner, *Phil. Mag.*, **48**, 719 (1924).

[3] Bieler, *Jour. Franklin Inst.*, **203**, 211 (1927).

[4] Fermi, *Zs. f. Phys.*, **36**, 902 (1926).

[5] Dirac, *Proc. Roy. Soc. A.*, **112**, 661 (1926).

a very serious consideration of the theory on the part of the physicist.

By far the larger number of applications has been to various points of the electron theory of metals, namely,

(*a*) The absence of a contribution of the free electrons to the specific heat of metals.[12]

(*b*) The approximate constancy of the paramagnetic susceptibility of the alkali metals.[7]

(*c*) The constancy of the ratio of thermal to electrical conductivity (Wiedemann-Franz Law).[12]

(*d*) The Volta effect.[12]

(*e*) Thermo-electric phenomena in metals.[12', 17]

(*f*) The emission of electrons from hot bodies.[12, 16]

(*g*) The existence of a sharp threshold frequency in photoelectric emission from metal surfaces.[14]

(*h*) The thermomagnetic and galvanomagnetic effects.[17]

Few applications of the Fermi-Dirac statistics have been made up to the present time outside the realm of the electron theory of metals. It is only rarely that ordinary matter occurs in the gaseous state under such conditions of high density and low temperature that the ordinary classical statistics do not apply just as well. There is a notable exception, however, in the case of the white dwarfs, those stars of which the companion of Sirius is an example, whose enormous density of the order of 50,000 grammes per cc. remained a mystery until Eddington[6] pointed out that it was a natural consequence of the very high state of ionization which their high temperature would cause. A recent application by R. H. Fowler[5] of the Fermi-Dirac statistics to the energy distribution among the component particles has completely cleared up a very serious difficulty which the first form of Eddington's theory presented.

It is hoped that this review will serve a purpose in bringing the new theory before those who have not had a chance to read the original papers, most of which appeared in German publications.[21] The treatment follows partly the lines of the original treatment by Fermi, but the connection between the Fermi-Dirac principle and the de Broglie wave has been taken from a paper by Pauli.[7]

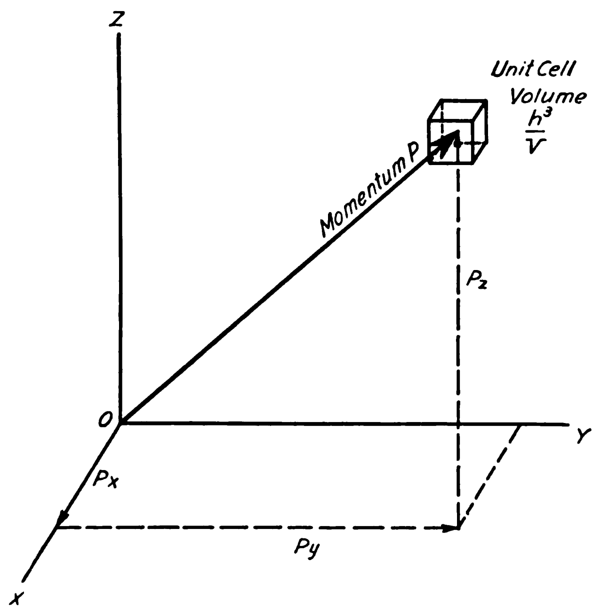
[6] Fowler (R. H.), *Monthly Notices, R.A.S.*, 87, 114 (1926).

[7] Pauli, *Zs. f. Phys.*, 41, 81 (1927).

2. GENERAL CONSIDERATIONS.

With the advent of the Quantum Theory and the introduction of definite energy states, there has been a change in the point of view of Statistical Mechanics. Instead of inquiring into the probability that the energy of an individual unit in an aggregate will lie in a given interval, the new statistical mechanics originated by Bose and Einstein[8] inquires into the probability that there will be one or more individuals in the class associated with a given energy state.

FIG. 1.



Division of the momentum space.

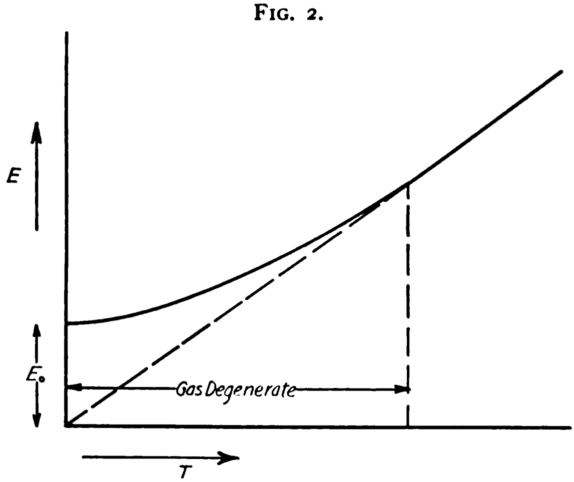
These authors consider a volume V of a monatomic gas and assume that corresponding to each of the molecules in volume V, there is drawn from a common origin a vector whose components are the three components p_x, p_y, p_z of its momentum p (Fig. 1). Each possible energy state then corresponds to a unit cell of volume h^3/V in this momentum space, and the number of molecules in each energy state is repre-

[8] Bose, *Zs. f. Phys.*, **26**, 178 (1924), Einstein, *Berl. Ber.*, 1924, p. 261, 1925, p. 3.

sented by the number of representative vectors that end in each cell. This subdivision of the momentum space into unit cells will seem arbitrary at this stage. It will appear in the next section how it follows from a consideration of the de Broglie wave associated with each molecule.

So far, the statistical methods of Bose-Einstein, and of Fermi-Dirac are in complete agreement.[9] On the one hand, however, Bose and Einstein assume that any number of molecules can be associated with each unit cell of volume h^3/V. Fermi and Dirac, on the other hand, extending the Pauli exclusion principle, which is known to hold for the several electrons within the atom, state that *the number of molecules associated with a given unit cell can only be 1 or 0*, and that either number is equally probable.

Fig. 2.



Relations between temperature and energy in a gas at low temperature.

At the higher temperatures, where the momenta are large, there is practically no restriction placed by the principle on the possible momenta. At low temperatures, the cells near the origin are nearly all filled, and there is a very distinct limitation on the possible momenta. At absolute zero, all the cells nearest the origin are filled, but there is still a very

[9] For a very interesting derivation of the Quantum Statistics of Bose-Einstein and of Fermi-Dirac, as well as Classical Statistics as special cases of a more general statistical treatment, see L. Brillouin, *Comptes Rendus*, 184, 589 (1927).

definite energy, or zero-point energy in the gas. This gas is then said to be *completely degenerate*.

The full line in Fig. 2 shows the relation between energy and temperature in a degenerate gas. The dotted part extending through the origin shows the relation in a non-degenerate gas. E_0 is the zero-point energy.

As we shall see later, the criterion of degeneracy is

$$\frac{n}{(2\pi mkT)^{3/2}},$$

where n = the number of molecules per unit volume, and
m = the mass of one molecule.

Hence, the temperature at which degeneracy first becomes felt varies as,

$$\frac{n^{2/3}}{m}.$$

It is about 5° absolute for Helium, it is therefore 36000° absolute for an electron gas containing the same number of particles per unit volume. Hence, the free electrons in a metal may be considered as forming a degenerate gas at all ordinary temperatures.

3. THE DISTRIBUTION FUNCTION IN A DEGENERATE GAS.

The distribution function will naturally differ from that of classical mechanics. Let us find the way in which energy W will distribute itself among the N molecules in volume V of a degenerate gas.

Pauli considers a cubical volume of side 1. Following de Broglie, he then associates with a molecule of momentum p a frequency ν related to it by the equation,

$$\frac{p}{h} = \frac{\nu}{v}, \tag{1}$$

where v is the velocity of propagation of the waves, and assumes that the number of possible momenta between p and $p + dp$ is equal to the number of possible stationary vibrations of frequencies between ν and $\nu + d\nu$ within the volume.

According to Rayleigh and Jeans, the number of possible frequencies between ν and $\nu + d\nu$ is,

$$Q(\nu, \nu + d\nu) = V \cdot \frac{4\pi\nu^2 d\nu}{v^3}. \tag{2}$$

Hence, the number of possible momenta between p and $p + dp$ is,

$$Q(p, p + dp) = V \cdot \frac{4\pi p^2 dp}{h^3}. \tag{3}$$

The quantity on the right-hand side is the number of unit cells of volume h^3/V in the portion of the momentum space comprised between radii p and $p + dp$. Hence, we have deduced from a consideration of the de Broglie waves, the fundamental fact of the Bose-Einstein statistical mechanics, namely that each possible state is associated with a unit cell of volume h^3/V in the momentum space.

Since the kinetic energy E of the molecule is given by,

$$E = \frac{p^2}{2m}, \tag{4}$$

when m is its mass, equation (3) may also be written,

$$Q(E, E + dE) = \frac{V}{h^3} \cdot 2\pi(2m)^{3/2}E^{1/2}dE. \tag{5}$$

This is the number of possible energy states. We must now find the way in which the molecules will be distributed among these states subject to the Fermi-Dirac restriction that there can be no more than one in each.

Let Q_s be the number of energy states between E_s and $E_s + dE_s$, and let N_s be the number of molecules distributed among these Q_s states. We have then,

$$N_s \leq Q_s, \tag{6}$$

$$N = \sum N_s, \tag{7}$$

$$W = \sum N_s E_s. \tag{8}$$

Also, the number of ways in which the N_s molecules can be distributed among the Q_s states is,

$$\binom{Q_s}{N_s} = \frac{Q_s!}{N_s!(Q_s - N_s)!}. \tag{9}$$

Hence, the number of ways in which the N molecules can be distributed among all the states is

$$P = \Pi\binom{Q_s}{N_s}. \tag{10}$$

Or, using Stirling's theorem,

$$\begin{aligned} \log P = & \quad \Sigma \log\binom{Q_s}{N_s} \\ = & - \Sigma\left(N_s \log \frac{N_s}{Q_s - N_s} + Q_s \log \frac{Q_s - N_s}{Q_s}\right). \end{aligned} \tag{11}$$

In the actual distribution N and W must be stationary and P a maximum. Now, from (II), we obtain,

$$\delta(\log P) = \Sigma \log \frac{Q_s - N_s}{N_s} \delta N_s. \tag{12}$$

Also, from (6) and (7),

$$\Sigma \delta N_s = 0, \tag{13}$$

$$\Sigma E_s \delta N_s = 0. \tag{14}$$

Hence, using undeterminate multipliers,

$$\Sigma\left\{\log \frac{Q_s - N_s}{N_s} - \alpha - \beta E_s\right\} \delta N_s = 0, \tag{15}$$

where α, β are arbitrary coefficients.

If this is to be true whatever the values of δN_s, then, we must have,

$$\log \frac{Q_s - N_s}{N_s} - \alpha - \beta E_s = 0 \tag{16}$$

or

$$\frac{N_s}{Q_s - N_s} = e^{-(\alpha + \beta E_s)} \tag{17}$$

Hence,

$$N_s = \frac{Q_s}{e^{\alpha + \beta E_s} + 1}, \tag{18}$$

where α and β satisfy the conditions,

$$N = \sum_0^\infty \frac{Q_s}{e^{\alpha+\beta E_s} + 1}, \tag{19}$$

$$W = \sum_0^\infty \frac{Q_s E_s}{e^{\alpha+\beta E_s} + 1}. \tag{20}$$

Hence, combining (5) and (18) we get,

$$N_s = N(E, E + dE) = \frac{V}{h^3} \cdot 2\pi(2m)^{3/2} E^{1/2} \frac{1}{e^{\alpha+\beta E} + 1} dE. \tag{21}$$

At low densities, and for large values of E, this should agree with the Maxwell distribution,

$$N^*(E, E + dE) = KE^{1/2} \cdot \frac{1}{e^{\frac{E}{kT}}} dE. \tag{22}$$

This will be so if

$$\beta = \frac{1}{kT}. \tag{23}$$

We must now evaluate α.
From (19) and (20), we obtain,

$$N = \frac{V}{h^3} \cdot 2\pi(2m)^{3/2} \int_0^\infty \frac{E^{1/2} dE}{e^{\alpha+(E/kT)} + 1}, \tag{24}$$

$$E = \frac{V}{h^3} \cdot 2\pi(2m)^{3/2} \int_0^\infty \frac{E^{3/2} dE}{e^{\alpha+(E/kT)} + 1}. \tag{25}$$

If we write $\frac{E}{kT} = x$ and put

$$F(\alpha) = \frac{2}{\sqrt{\pi}} \int_0^\infty \frac{x^{1/2} dx}{e^{\alpha+x} + 1}, \tag{26}$$

$$G(\alpha) = \frac{4}{3\sqrt{\pi}} \int_0^\infty \frac{x^{3/2} dx}{e^{\alpha+x} + 1}, \tag{27}$$

we obtain, instead of (24) and (25),

$$N = V \cdot \frac{(2\pi mkT)^{3/2}}{h^3} F(\alpha), \tag{28}$$

$$E = \frac{3}{2} V \frac{(2\pi mkT)^{3/2}}{h^3} G(\alpha) = \frac{3}{2} NkT \frac{G(\alpha)}{F(\alpha)}. \tag{29}$$

For very large values of α, corresponding to densities and temperatures where the gas is not degenerate, we can easily obtain $F(\alpha)$ and $G(\alpha)$ in the form of a series, namely,

$$F(\alpha) = e^{-\alpha} - \frac{e^{-2\alpha}}{2^{3/2}} + \frac{e^{-3\alpha}}{3^{3/2}} - \cdots, \tag{30}$$

$$G(\alpha) = e^{-\alpha} - \frac{e^{-2\alpha}}{2^{5/2}} + \frac{e^{-3\alpha}}{3^{5/2}} - \cdots. \tag{31}$$

To a first approximation, $F(\alpha) = G(\alpha) = e^{-\alpha}$, so that (28) and (29) reduce to

$$\alpha = \log \left\{ \frac{V}{N} \frac{(2\pi mkT)^{3/2}}{h^3} \right\} \tag{32}$$

and,

$$E = \frac{3}{2} NkT, \tag{33}$$

as in the Classical theory.

When α assumes large negative values, on the other hand, corresponding to strong degeneration, $F(\alpha)$ and $G(\alpha)$ assume the assymptotic forms,

$$F(\alpha) = \frac{4}{3\sqrt{\pi}}(-\alpha)^{3/2}\left[1 + \frac{\pi^2}{8\alpha^2} + \cdots\right], \tag{34}$$

$$G(\alpha) = \frac{8}{15\sqrt{\pi}}(-\alpha)^{5/2}\left[1 + \frac{5\pi^2}{8\alpha^2} + \cdots\right]. \tag{35}$$

Hence, substituting for $F(\alpha)$ in (28), we obtain,

$$\alpha = -\frac{1}{8}\left(\frac{6}{\pi}\frac{N}{V}\right)^{2/3} \frac{h^2}{mkT}\left\{1 - \frac{16\pi^2}{3}\left(\frac{\pi}{6}\cdot\frac{V}{N}\right)^{4/3}\frac{m^2k^2T^2}{h^4} + \cdots\right\}, \tag{36}$$

which gives for the zero-point energy,

$$\frac{E_0}{N} = \frac{3}{40}\left(\frac{6}{\pi}\right)^{2/3}\frac{h^2}{m}\left(\frac{N}{V}\right)^{2/3}. \tag{37}$$

Further, if we differentiate E, given by equation (29) with respect to T, we obtain the specific heat at constant volume per gramme-molecule, namely,

$$c_v = \frac{L}{N}\frac{dE}{dT} = \left(\frac{4\pi}{3}\right)^{2/3}\frac{\pi^2 Lmk^2T}{h^2n^{2/3}}, \tag{38}$$

where L is the number of molecules per gramme-molecule and n the number per unit volume.

4. APPLICATIONS TO THE ELECTRON THEORY OF METALS.

(a) *Zero-Point Energy and Specific Heats.*

A large number of phenomena connected with the flow of electricity in metals, namely electrical and thermal conductivity, thermoelectric, and photoelectric effects have long been explained in terms of the presence in metals of a number of free electrons, of the order of one per atom. On the classical ideas of equipartition these electrons ought to share in the heat motion of the atoms, and therefore to reveal their presence in specific heat measurements. This, they have always failed to do; it is a well-known fact that metals obey the law of Dulong and Petit, and that the whole of the specific heat is accounted for as atomic heat.

The application by Sommerfeld [12] of the Fermi-Dirac statistics to the electron gas formed by these free electrons within the metal seems at last to have cleared up the difficulty, and at the same time to have given a very much more satisfactory explanation of a number of other electrical phenomena in metals.

We have seen that an electron gas ought to show signs of becoming degenerate at temperatures of the order of 36000° C. At ordinary temperatures, degeneration will be practically complete, and the average energy of the electrons will be very near the zero-point energy.

In calculating this, however, we must bear in mind one point. The statistics developed up to now have referred to molecules which possess no energy beyond their energy of translation. The spinning electron of present-day theory [9] has energy of rotation as well. In a magnetic field, it will set itself with its axis of spin in the direction of the field, but its

[9] Goudsmith and Uhlenbeck, *Nature*, 117, 264 (1926).

rotation may be in either direction about that axis. Since the angular momentum is perfectly definite in either case, the electron may exist in two and only two states. It has statistical weight 2. The natural extension of the Fermi-Dirac statistics to the case of the electron is to allow two electrons, one in each direction of spin, in each cell of the momentum space. This leads us to replace n by $n/2$ in the formula for the zero-point energy and for the specific heat.

On substituting numerical values in equation (37), we get for the zero-point energy of the electrons in the case of sodium,

$$\frac{E_0}{N} = 3.14 \times 10^{-12} \text{ ergs.}$$

This is the energy which an electron would possess at 15000° C. on the old equipartition theory. The corresponding voltage is 2 volts.

As for the specific heat, we find, on substituting numerical values in (38) that the contribution of the electrons at ordinary temperatures is of the order of one hundredth of that of the atoms. Hence, we should not expect to detect it in specific heat measurements at ordinary temperatures.

Having regard to the high energy of the electrons at ordinary temperatures, and to their very low specific heats, we see at once why it is that no variation with temperature of the photoelectric threshold has been detected. This experimental fact was also hard to reconcile with the classical electron theory of the metals.

(*b*) *The Susceptibility of the Alkali Metals.*

One of the first successes of the statistical method of Fermi and Dirac was its application by Pauli [7] to the susceptibility of the alkali metals in the solid state. This is known to be paramagnetic and practically independent of temperature. It may be expected to consist of: (*a*) a diamagnetic contribution of the rare-gas like cores, (*b*) the contribution of the valency electrons, which may be diamagnetic or paramagnetic.

The susceptibility of an electron gas composed of rotating electrons which are magnetic doublets might be expected to follow the Curie law,

$$k \propto \frac{1}{T}$$

and to become enormous at low temperatures.

If the electron gas becomes degenerate at such temperatures, however, this will not be the case. Two electrons of equal and opposite magnetic moment in one cell of the momentum space will give no contribution to the susceptibility. At low temperatures the states corresponding to low momenta will tend to become fully occupied. Hence the susceptibility will remain small.

The formula for the susceptibility is easily obtained from the consideration of the change in the distribution function due to the mutual energy of the magnetic field and the electron. Pauli [7] finally obtains for the susceptibility in the case of complete degeneration,

$$x_0 = 4(\pi/6)^{2/3}G^{2/3}\frac{\mu^2 n^{1/3} m_0}{h^2},$$

where G is the statistical weight of the state, always 2 for the electron,

$$\mu = \sqrt{3}\,\mu_0,$$
$$\mu_0 = 0.921 \times 10^{-20} \text{ e.m.u.}$$

and n = the number of electrons per unit volume, equal in this case to the number of atoms.

Putting in numerical values, we obtain the calculated values in the table below.

TABLE I.

Susceptibility of the Alkali Metals.

Metal	Na.	K.	Rb.	Cs.
Calculated				
Pauli,[7]	0.66×10^{-6}	0.52×10^{-6}	0.49×10^{-6}	0.45×10^{-6}
Observed				
McLennan, Ruedy and Cohen [10]	0.61	0.42	0.31	0.42
Lane [11]	0.65	0.54		

The agreement between theory and experiment is still far from perfect, but no other theory gave even an approach to

[10] McLennan, Ruedy & Cohen, *Proc. Roy. Soc. A.*, 118, p. 468.

[11] Lane, *Proc. Roy. Soc. Can.*, 1928.

the experimental results. It should be remembered, however, that no correction has been applied to Pauli's results for the diamagnetic contribution of the atom cores. This would notably lower the theoretical estimate and actually lead us to expect K, Rb and Cs to be diamagnetic.

(*c*) *The Wiedemann-Franz Law.*

The application of the Fermi-Dirac statistics to the problem of electrical and thermal conductivities also shows a marked improvement over the earlier theories. The calculations of Sommerfeld [12] follow exactly the classical treatment of Lorentz,[13] the law of distribution of Fermi being substituted for that of Maxwell. At high temperatures and low densities the formulæ obtained agree exactly with those of Lorentz. At low temperatures and high densities, however, where degeneration is almost complete, the formulæ obtained differ markedly from the classical ones. They are

Electrical conductivity:

$$\sigma = \frac{8\pi}{3}\frac{e^2 l}{h}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{39}$$

Thermal conductivity:

$$K = \frac{8\pi^3}{9}\frac{lk^2T}{h}\left(\frac{3n}{8\pi}\right)^{2/3}, \tag{40}$$

where l is the mean free path and k the gas constant per molecule. These formulæ are not satisfactory for comparison with experiment, since the mean free path, which occurs in both, is a quantity about which we know very little.

The ratio (K/σ), however, is independent of the free path and admits of direct comparison with experiment. The theory gives,

$$\frac{K}{\sigma} = \frac{\pi^2}{3}\left(\frac{k}{e}\right)^2 T. \tag{41}$$

It is well known that the theories of Drude and Lorentz give expressions of the same form, with numerical factors 3 and 2 however.

[12] Sommerfeld, *Naturwissenschaften*, 15, 825 (1927); *Zs. f. Phys.*, 47, 1 (1928).

[13] Lorentz, "Theory of Electrons" (Teubner). Note 29.

The numerical results at 18° C. are as follows:

	Drude.	Lorentz.	Sommerfeld.	Experiment.
$\frac{K}{\sigma} \times 10^{-10}$	6.3	4.2	7.1	7.11

The experimental result quoted is one given by Sommerfeld for the average of the values for the 12 metals, Al, Cu, Ag, Au, Ni, Zn, Cd, Pb, Sn, Pt, Pd, Fe. The closeness of agreement may be slightly fortuitous, for the values for some of the metals chosen differ as much as 10 per cent. from the average, but there is no doubt that the new theory fits the numerical results much better than that of Lorentz.

(*d*) *The Voltaic Difference of Potential, Photoelectricity, and Thermionic Emission.*

The application of the Fermi-Dirac statistics to the explanation of the Voltaic difference of potential, of photoelectricity and of thermionic emission has brought about a similar improvement over the earlier theories. These phenomena are all concerned with the work required to remove an electron from the interior of the metal into the space outside. They will therefore be considered together.

A certain amount of work W_0 is required to remove a free electron at rest from the interior of a metal. If this electron already possesses kinetic energy T, the work is reduced to,

$$W = W_0 - T. \tag{42}$$

Now, in a degenerate gas, the momenta actually possessed by the molecules will be the lowest compatible with the application of Fermi's extension of the Pauli exclusion principle. The total number of molecules with energies not exceeding E_{max} can therefore be obtained by integrating equation (5).

We get

$$n = \frac{1}{V}\int Q(E)dE = \frac{4\pi}{3}\left(\frac{mE_{max}}{h^2}\right)^{3/2}. \tag{43}$$

Hence,

$$E_{max} = \frac{h^2}{2m}\left(\frac{3n}{4\pi}\right)^{2/3}. \tag{44}$$

If the molecule can possess energy in addition to translational energy, equation (44) must be altered by inserting the appropriate value of the statistical weight G, 2 in the case of the electron. Hence,

$$E_{\max} = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{45}$$

As Fowler [14] has pointed out, $E_{\max}$ is not an absolute maximum. It is simply a value which is only exceeded by a very small proportion of the electrons. Putting $T = E_{\max}$, we obtain, for the electrons which are most easily removed,

$$W = W_0 - \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{46}$$

If, as in Frenkel's [15] earlier theory of electronic conduction, we apply the Virial Theorem, and say that the potential energy is twice the kinetic, and opposite in sign, we get,

$$W = 2T - T = T = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{47}$$

The voltaic difference of potential between two metals, 1 and 2, is therefore,

$$V_1 - V_2 = \frac{W_2}{e} - \frac{W_1}{e} = \frac{h^2}{2m}\left(\frac{3}{8\pi}\right)^{2/3}(n_2^{2/3} - n_1^{2/3}). \tag{48}$$

This is the same as Sommerfeld's formula, except for the inclusion of the statistical weight 2 of the electron. The difference of potential between Na and Ag accordingly comes out at 3.6 volts instead of 5.7 given by his calculation. The electrochemical series of elements comes out in the proper order for all those metals for which we are entitled to assume that the number of conducting electrons per atom is one.

As Fowler [14] has pointed out, the fact that the electron gas in a metal is almost completely degenerate at ordinary temperatures provides a ready explanation for the existence of a sharp photoelectric frequency.

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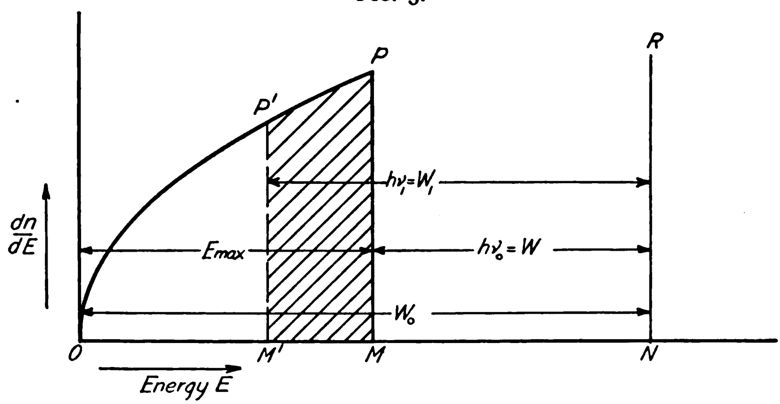
[14] Fowler (R. H.), *Proc. Roy. Soc. A.*, **118**, 229 (1928).
[15] Frenkel, *Zs. f. Phys.*, **29**, 214 (1924).

The electrons which are most easily removed will just be ejected from the metal by frequency ν_0, where,

$$h\nu_0 = W = W_0 - \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{2/3}. \tag{49}$$

The variation of emission with frequency is best illustrated by means of a slight modification of a figure given by Fowler (Fig. 3).

Fig. 3.



Energy relations in the photoelectric effect.

The distribution curve on an energy base is the parabolic arc OP, followed by the sharp drop PM, corresponding to kinetic energy $E_{max} \cdot ON = W_0$ is the kinetic energy which an electron must have in order to be just able to escape through the surface. As the frequency ν of the incident radiation is gradually increased, no electrons will be emitted until ν reaches the value ν_0, when the electrons with maximum kinetic energy can just attain the required critical velocity by absorbing energy $h\nu$. When ν has increased to ν_1, corresponding to energy $W_1 = h\nu_1$, all the electrons represented by area $MPP'M'$ can reach the required critical velocity on absorption of the radiation. Hence the observed sharp photoelectric threshold at frequency ν_0 and the increase in emission as ν is increased above ν_0.

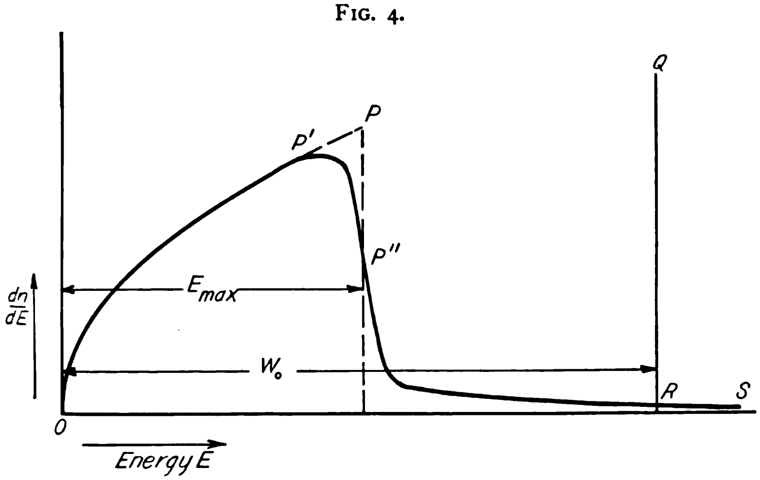
Under actual conditions, PM is not exactly a vertical straight line, but a rapidly falling exponential curve. However, the sharpness of the experimental curve is amply

accounted for. It should be noticed that the theory also accounts for the constancy of the photoelectric threshold as the temperature is varied, since E_{max} does not depend on the temperature.

A closer inspection of the same diagram also accounts for thermoelectric emission. The quantitative treatment is given in papers by Nordheim [16] and Sommerfeld.[12] We shall content ourselves here with a qualitative view of the matter. As equation (21) indicates, the distribution law for large values of E becomes

$$N(E, E + dE) = \frac{V}{h^3} 2\pi(2m)^{3/2}E^{1/2}e^{-(\alpha + E/kT)}\, dE. \qquad (50)$$

FIG. 4.



Energy relations in the thermoelectric effect.

Hence, there is always a certain number of electrons present with large energies, and the number increases with the temperature. The result is that, at high temperatures, the distribution curve of Fig. 3 assumes more the form of that of Fig. 4.

The electrons under the curve to the right of R possess more than the critical velocity for emission, and may escape if they are near the surface, and if they are properly directed. Taking into account the direction, Nordheim and Sommerfeld

[16] Nordheim, *Zs. f. Phys.*, 46, 833 (1928).

obtained exactly the formulæ obtained by Dushman as a modification of the well known Richardson formula for the case in which the electron gas is degenerate.

The thermoelectric effects, the thermomagnetic and the galvanomagnetic effects have also been treated with very promising results by Sommerfeld.[17] The experiments of Millikan and Eyring[18] on the pulling out of the electrons from metals by means of electric fields have also been satisfactorily accounted for by W. V. Houston.[19]

5. SOME OUTSTANDING PROBLEMS.

The initial phase in building up a satisfactory electron theory of metals on the basis of the Fermi Principle may be regarded as complete. This has been done practically without consideration of the structure of the atomic cores of the lattice. The second step will involve a much closer consideration of the structure of the metals concerned and should lead to a calculation of the free path, the number of free electrons available per atom and the work done by an electron in escaping from the surface. It should also lead to a plausible explanation of superconductivity and of the results obtained by Bridgman[20] on the variation of conductivity with pressure. The work is thus by no means complete, but the application of the principle of Fermi and Dirac has been a definite step forward in our understanding of electronic phenomena in metals.

MACDONALD PHYSICS LABORATORY,
McGILL UNIVERSITY,
MONTREAL,
April 19, 1928.

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[17] Sommerfeld, *Zs. f. Phys.*, **47**, 43 (1928).

[18] Millikan and Eyring, *Phys. Rev.*, **27**, 51 (1926).

[19] Houston, *Zs. f. Phys.*, **47**, 33 (1928).

[20] Bridgman, **27**, 68 (1926).

[21] An excellent short article by H. F. Biggs, summarizing recent progress in these lines has since appeared in *Nature*, **121**, 503 (1928).

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

TWENTY-FIRST NATIONAL CONFERENCE ON WEIGHTS AND MEASURES.

THE Twenty-First National Conference on Weights and Measures was held at the Bureau of Standards on May 22 to 25, inclusive. The following outstanding accomplishments resulted from this conference: Final regulations for lubricating-oil bottles and a new code of specifications and tolerances for grease-measuring devices were adopted; final action was taken on a series of amendments to the regulations for liquid-measuring devices and, largely for purposes of clarification, a series of amendments to the regulations previously adopted for linear, fabric-measuring, and liquid-capacity measures, vehicle tanks, and scales were adopted. Based upon an investigation conducted by the bureau, the transmission drive for taximeters was endorsed.

In point of attendance and the number of States represented the conference surpassed all previous ones. Delegates were present from 28 States and the District of Columbia, and the registration of delegates and official guests reached 246, of which number, 127 were weights and measures officials or representatives. The list of States having delegates in attendance was as follows: Alabama, California, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

The opening address of the President of the Conference, Dr. George K. Burgess, was of particular interest. It was devoted largely to a refutation of the misleading and incorrect statements which have been so generally circulated recently among weights and measures officials and manufacturers relative to H. R. 7208, the bill introduced into the

* Communicated by the Director.

present Congress at the instance of the Twentieth National Conference on Weights and Measures. "A bill to regulate and control the manufacture, sale, and use of weights and measures and weighing and measuring devices for use or used in trade and commerce, and for other purposes." Dr. Burgess included in his address a résumé of the provisions of this bill, a statement of the facts leading up to its introduction into Congress, answers to a number of questions relating thereto originating with the American Institute of Weights and Measures, and a statement of the attitude of the National Bureau of Standards toward the agitation for and against the compulsory adoption of the metric system of weights and measures for the United States a subject which some persons have confused with the object of the above bill. In this connection he said: "As to the attitude of the Bureau of Standards in relation to the compulsory adoption of the metric system, we may state that the facts in the case are that in relation to all proposals advocating the compulsory adoption of the metric system of weights and measures in the United States the policy of the Bureau of Standards is one of neutrality—neither to advocate nor to discourage. The whole subject of compulsory adoption is a highly controversial one and diametrically opposite views are being freely voiced. Most of these are matters of opinion and definite facts are difficult to obtain. So many factors enter into the equation of compulsory adoption that the bureau is disinclined to make the attempt to evaluate it and thus throw the weight of its decision upon the one side or the other. Therefore, I can say definitely and emphatically that the bureau is not advocating the adoption of the metric system for commercial or industrial uses whether by legislation or otherwise, nor has it ever done so during the period that I have been director of the bureau."

Aside from numerous technical subjects considered, the conference program featured several addresses by representatives of business and industry. O. C. Adams, president of the Southern Division of the Great Atlantic and Pacific Tea Company, spoke upon the weights and measures aspects of chain-store operation, and described the steps taken by his organization to meet, and in some instances to anticipate, weights and measures regulations. The general manager of

the National Better Business Bureau, Edward L. Greene, told the conference of many specific instances in which there had been splendid coöperation between weights and measures officials and local better business bureaus. The reweighing of loads of coal, check-ups on gasoline purchases, the reweighing of packages of commodities put up by local dealers, and certain investigations of advertised claims were among the examples cited as typical of a general program on the part of the better business organizations to support and assist in the supervisory activities of the weights and measures official. A. Bousfield, chief engineer of the E. and T. Fairbanks Company, gave a very interesting presentation of the subject, "The Development of Industry," which he illustrated with a large number of lantern slides.

One of the important subjects considered at the conference was the testing of gasoline meters. This subject was presented in two parts, first, testing in the field as carried on by weights and measures officials, and second, testing in the factory as carried on by the manufacturers of meters. Papers describing their methods of conducting field tests were presented by William Foster, city sealer of Springfield, Mass., Theo. A. Seraphin, district supervisor of weights and measures of Philadelphia, Pa., Frank Berka, deputy sealer of Los Angeles, Calif., and John A. Stephenson, city sealer of Rochester, N. Y. Speaking for their respective companies, C. P. Griffith of S. F. Bowser and Company, George D. MacVeagh of the National Meter Company, A. D. MacLean of the Pittsburgh Equitable Meter Company, and H. F. Barrett of the Buffalo Meter Company told of the equipment and methods followed in the factory testing of meters designed for dispensing gasoline at filling stations.

A varied and interesting group of papers was presented by weights and measures officials. Joseph J. Rogers, assistant superintendent of weights and measures of New Jersey, described the recently acquired heavy-scale-testing equipment of his State, while the equipment and methods being utilized in Texas in the regulation of gas, electric, and water meters were described by W. T. Hendrichson, meter inspector of the State division of weights and measures. J. H. Meek, director of the division of markets of Virginia, spoke on coöperation

among weights and measures officials to the end that more nearly uniform regulations may be promulgated and enforced by the several States, while a unique and highly successful method of promoting interest in weights and measures supervision in a given community by essay contests in the high schools, was described in a paper prepared by James J. Dawson, inspector of standards of Massachusetts and the originator of the plan. In the absence of Mr. Dawson, this paper was presented to the conference by Mr. Francis Meredith, director of standards for Massachusetts. The efforts of two State weights and measures associations to keep their members in touch with one another between annual meetings of the association, through the medium of publications supported by the associations, was told by the editor of one of these publications, A. W. Corwin, county sealer of Allegany County, New York. H. N. Davis, deputy commissioner of weights and measures for Vermont, told of the serious effects upon weighing equipment of the recent flood conditions in New England and of the immediate calls made upon weights and measures officials to recondition this equipment for emergency use in the distribution of supplies throughout the stricken area.

Of interest in connection with the testing of heavy-capacity scales was the description given by H. W. Hem of the Toledo Scale Company of the testing device recently developed by his company. This device is designed to test a scale up to 20,000 pounds, and is an outgrowth of the earlier devices of similar character but much smaller capacity which this company has also made.

Some features of the installation of the new plate-fulcrum, master railroad track scale of the Bureau of Standards at Clearing Yard, Chicago, were described by H. M. Roeser of the bureau, who had charge of this installation. This scale will be used for the purposes of calibrating railroad-owned track-scale-testing cars, the test cars and weights belonging to the Bureau of Standards, large weights for industrial uses, etc. The master scale is housed in a special building suitably equipped for carrying on the activities of a testing depot, and will be in charge of members of the track scale section of the Bureau of Standards.

I. J. Fairchild of the commercial standards unit of the bureau reviewed the development of this unit, and described some of the various projects at present occupying the attention of its personnel. Commercial standards, it was explained, are standards which the producers want as a guide for fabrication, and define articles which the distributors want to stock and which the consumers want to buy. In the establishment of commercial standards, the Bureau of Standards relies entirely upon coöperation, and in this field makes no suggestions relative to the standards except upon special request for advice; the procedure is a natural outgrowth of the movement toward the elimination of waste in industry through the limitation of unnecessary variety or the restriction of needless diversification of types, sizes, colors, etc.

A proposed publication of the Bureau of Standards was announced in a paper presented by William Parry of the bureau. A digest of weights and measures cases is planned, to present in one volume an index to weights and measures cases decided throughout the United States, with special analyses appended in connection with those involving outstanding or unusual principles. This publication should prove valuable to all weights and measures officials who have occasion from time to time to present cases in court, for they will be enabled to locate readily decisions previously rendered on similar questions in their own or other States.

A report of the investigation of the Bureau of Standards on the transmission drive for taximeters was made by Ralph W. Smith, who stated the conclusion that, as a result of many observations made on taxicabs and a private car equipped with two meters each, one driven from the front wheel and the other from the transmission, the differences in registration were negligible from the weights and measures standpoint. He added that, in view of numerous advantages which the transmission drive appears to possess as compared with the front-wheel drive, it was recommended that the former be accepted by officials as a proper method of installation for taximeters. Later, the conference, by resolution, went on record as being in agreement with these conclusions.

The special committee on legislation, appointed at the last conference, reported the preparation and introduction

into Congress of H. R. 7208, "A bill to regulate and control the manufacture, sale, and use of weights and measures and weighing and measuring devices for use or used in trade or commerce, and for other purposes." This action was taken in conformity with the instructions of the twentieth national conference. In presenting this report, the chairman of the committee, E. J. Maroney, sealer of weights and measures of New Haven, Conn., denounced recent attacks made upon the National Bureau of Standards in connection with the bill in question by those opposing its passage. Later in the meeting, Mr. Maroney presented a petition for the signature of the members of the conference, this petition setting forth the facts in relation to the introduction of the conference bill, and asserting the confidence of the conference in the integrity of the motives of the Bureau of Standards.

The newly elected officers of the National Conference on Weights and Measures are as follows: President, Dr. George K. Burgess, Director of the Bureau of Standards; first vice president, H. L. Flurry, chief of the division of weights and measures for Alabama; second vice president, Francis Meredith, director of standards for Massachusetts; secretary, F. S. Holbrook, co-chief of the division of weights and measures of the Bureau of Standards; and treasurer, George F. Austin, sealer of weights and measures for Detroit, Mich.

At the Twentieth National Conference held last year, it was decided that in the future there should not be more than one member on the executive committee of the conference from any given State. In accordance with this decision, the following executive committee was elected: All of the officers, ex officio; W. F. Cluett, of Illinois; H. N. Davis, of Vermont; Thomas Flaherty, of California; William Foster, of Massachusetts; S. T. Griffith, of Maryland; T. F. Mahoney, of Tennessee; E. J. Maroney, of Connecticut; I. L. Miller, of Indiana; A. B. Smith, of Pennsylvania; W. A. Payne, of New York; V. A. Stovall, of Texas; C. V. Fickett, of Maine; B. W. Ragland, of Virginia; C. W. Roberts, of the District of Columbia; W. F. Steinel, of Wisconsin; H. A. Webster, of New Hampshire; H. S. Jarrett, of West Virginia; J. H. Foley, of New Jersey; and M. A. Bridge, of Ohio.

CONFERENCE OF UTILITY COMMISSION ENGINEERS.

THE sixth annual conference of state utility commission engineers, held at the bureau May 31 and June 1, was attended by 24 engineers from 12 states, the District of Columbia and two provinces of Canada. The widespread interest in these meetings is shown by the fact that California, Oklahoma, Iowa, Wisconsin, Florida, and Alabama were represented, in addition to most of the northeastern states which have commissions actively interested in engineering problems.

The value of these conferences arises not merely from the engineering papers presented and discussed but even more from the personal contacts established, the opportunity to compare experience, and the interchange of information as to the way in which the engineering organizations of the several states operate. Questions of a more or less detailed sort arising from the operations of the commissions constitute a large part of the program. Since these questions are treated from the point of view of the commissions rather than in their more general aspects, the proceedings of the conference are not published.

The bureau acts as host for these conferences, but the programs are arranged by a committee of the engineers and include commission problems outside the scope of the bureau's work. The papers included in this year's program were as follows: "Depreciation in Connection with Appraisals," by H. Carl Wolf, chief engineer, Maryland Public Service Commission; "Effect of Reduced Cost of Steam Generation on Development and Potential Value of Water Powers," by C. M. Larson, chief engineer, Railroad Commission of Wisconsin; "A Fuel-price Clause in Rates for Domestic and Commercial Gas Service," by A. G. Mott, chief engineer, California Railroad Commission; "Inducement Form of Rate for Residential Use of Gas and Electricity," by C. R. Vanneman, chief engineer New York Public Service Commission; "Development of Rural Electric Service in California," by A. V. Guillou, assistant chief engineer, California Railroad Commission; "Gas Service Problems in Connection with the Revision of Bureau of Standards Circular 32," by E. R. Weaver, chemist, Bureau of Standards; "Accidents and Approved Protective Devices at Grade Crossings of Railroads and Highways," by E. Irvine

Rudd, chief engineer, Connecticut Public Utilities Commission; "Discussion of Fourth Edition of National Electrical Safety Code," by M. G. Lloyd, electrical engineer, Bureau of Standards.

The committee elected to take charge of the 1929 conference consists of A. G. Mott, chief engineer, Railroad Commission of California, chairman; Col. Philander Betts, chief engineer, New Jersey Board of Public Utility Commissioners, vice-chairman; I. F. McDonnell, chief engineer, Alabama Public Service Commission; and J. Franklin Meyer of the bureau, as secretary.

ELECTROLYSIS SURVEYS BY LOCAL UTILITIES COMPANIES.

Within the last year the Bureau of Standards has had several requests for assistance in determining the condition of underground structures with respect to electrolytic corrosion. The bureau's staff of electrolysis engineers has been reduced to one man, and it is no longer conducting field research in electrolysis. It is possible, however, in some cases to assist local utilities in improving their electrolysis conditions if all of the utilities concerned in a given locality are willing to coöperate. At present the bureau's engineer is directing two electrolysis surveys, one in Buffalo, and the other in Duluth. In each case a local electrolysis committee has been formed and a local engineer selected to collect data with the assistance of men furnished by each of the coöperating utilities.

From time to time the bureau's engineer visits the electrolysis committees and advises them as to what data are needed, the interpretation of their results and the steps to be taken to improve electrolysis conditions. The entire expense of the survey is borne by the local utilities. This method of handling electrolysis problems seems to have some advantages in cases where the local utilities wish to solve their own problems without the assistance of a consulting engineer. Not the least of these advantages is the better understanding by each local engineer of the viewpoints and problems of utility organizations other than his own.

CODE FOR ELECTRICITY METERS

THE third edition of the code for electricity meters has been issued by the sectional committee that has had the revision in charge. The Bureau of Standards, the Association of Edison Illuminating Companies, and the National Electric Light Association have been the sponsors for the project, under American Engineering Standards Committee procedure. The chairman of the sectional committee was a member of the staff of the bureau, and the work of revision has been carried on under his direction. On the sectional committee were representatives of the manufacturers of electricity meters, of public utility companies, public service commissions, municipal electricians, scientific instrument makers, and testing and research laboratories.

The code contains chapters on definitions, standards, metering, installation methods, laboratory and service tests, and specifications for the acceptance of types of watthour and demand meters, and auxiliary apparatus for use with meters. It is published by the National Electric Light Association (420 Lexington Avenue, New York, N. Y.), one of the sponsors, from whom copies are obtainable at $2.00 each.

THE STATUS OF FREQUENCY STANDARDIZATION.

IN a paper which appeared in the May, 1928 *Proceedings of the Institute of Radio Engineers*, p. 579, under this title, J. H. Dellinger, chief of the radio section of the bureau, shows that frequency standardization, of hitherto laboratory character only, has become of first-rank importance in reducing radio interference. The recent International Radio Conference recognized frequency as the cornerstone in the radio structure by devoting its major attention to a frequency allocation to provide for the orderly development of all radio services.

Because of increasing use of all available radio channels, particularly those for broadcasting and the very high frequencies, the requirements of frequency measurements are a hundred times more rigorous than they were five years ago. The perfection of standards and measurements to the necessary accuracy requires the most intensive work by the Government and by various large organizations to produce

standards and instruments that can be used to keep radio stations each operating on its own channel. This development has been facilitated by a special coöperative plan organized by the Bureau of Standards a year ago and involving the Commerce, Navy, and War Departments, the General Electric Company, the Westinghouse Company, American Telephone and Telegraph Company, Radio Corporation, and the General Radio Company.

Piezo oscillators are now available to hold radio station frequencies extremely constant. For instruments of this type equipped with temperature control, national and international comparisons have shown that they are reliable to a few parts in 100,000.

This brings in sight the possibility of the use of special piezo oscillators in broadcasting stations, which will hold the frequency so close that several such stations can operate simultaneously without heterodyne interference on the same frequency. This is the only practical scheme so far developed for solving the problem of too many broadcasting stations.

The use of frequency standards of this high accuracy is also vital to all users of the very high frequencies. Many more high frequency channels will become available when all stations use the best available frequency standards and keep the stations on their frequencies with great accuracy.

MEASUREMENT OF LARGE VOLUMES OF GAS.

This is the fourth year in which the Bureau of Standards has actively coöperated with the gas measurement committee of the Natural Gas Department of the American Gas Association on methods for measuring large volumes of gas.

In 1925, the first year of this work, the committee conducted some tests on three orifices against a covered gas holder, made available for the work by the East Ohio Gas Company of Cleveland, Ohio. The object of these tests was to determine the discharge coefficients for these orifices under very definite and limited conditions.

The next year, 1926, the work undertaken was a study of the effects of many types and combinations of pipe fittings at various distances from the orifice, and also the effectiveness of

different designs of straightening vanes in eliminating the disturbances produced by the fittings. As a result of this work, which was conducted at the plant of the Iroquois Gas Corporation, Buffalo, New York, the committee prepared and issued a tentative code on the installation of orifice meters. Copies of this code may be obtained by writing to the American Gas Association, Natural Gas Department, New York, N. Y.

During 1927 the work of 1926 continued, using a slightly modified set-up to check the disturbance measurements. Several important conclusions have been drawn from these experiments, among them the following:

When a swedge is used upstream from the orifice, straightening vanes must not be used between the swedge and orifice if a larger orifice flange is installed.

Disturbances caused by a combination of various fittings have an effect proportional to the distance of the disturbance from the orifice in terms of pipe diameter. In other words, the usual theory of geometrical relationships is found to hold.

Last year an extensive series of tests was started in order to study the effect on the discharge coefficient of changing the rate of flow. This series served as a check on similar tests made by the Bureau of Standards at Edgewood Arsenal, and showed changes of the same kind and approximately the same magnitude as recorded in the previous tests.

During the coming summer the work at Buffalo will be continued in line with a program decided upon some time ago. The preliminary arrangements included the installation of a new 4-inch pipe in a so-called commercial line, with two orifice flanges. Tests will be made with 25, 50 and 75 per cent. diameter ratio orifices at the highest possible pressure, followed by ones at lower pressures.

When making the tests at high line pressures it will be necessary to make some auxiliary tests on the gas itself to determine its super-compressibility, i.e., its deviation from Boyle's law, and also to determine the specific gravity of the gas as referred to air. An instrument for determining the super-compressibility of a gas has been constructed at the Bureau, and trial tests with it on air and carbon dioxide have given results in satisfactory agreement with existing data.

After these tests, and with the 4-inch line still in place, the

rate of flow tests will be checked using 25, 50, and 75 per cent. orifices. The 4-inch will then be replaced by a 12-inch line set-up with vanes and pressure taps at points geometrically similar in location to those used last year for the 8-inch line, and tests made with 25, 50, and 75 per cent. (diameter ratio) orifices at rates of flow as high as can be obtained.

If the results of tests on the 4-and 12-inch lines indicate the need for further work on orifices or pipes of other sizes, such as 2-inch pipe, this work will be undertaken if time permits. In addition, tests on 6 x 8, $6\frac{1}{2}$ x 8, and 7 x 8 inch orifices have been recommended in order to indicate the probable accuracy of measurements in these sizes.

Tests to supplement those on the 4-inch line at high static pressures will probably be carried out at another location, where pressures up to at least 350 lbs./in.^{2} are available. These tests would be started as soon as those on the 4-inch line at Buffalo are completed, and would be carried along with the other runs. This will mean that two crews will be kept at work for a large part of the time. H. S. Bean, chief of the gas measuring instrument section of the bureau, has been assisting the committee in developing its program and since last year has been in charge of the actual testing.

The question of extending these investigations to some mid-continental field, where pressures of 600 lbs./in.^{2} or more are available, is being considered by the committee. This is an important question because there are already in service transmission lines with working pressures of 500 lbs./in.^{2} or higher. Some tests may also be needed on casinghead gas at sub-atmospheric pressures. These tests would be complicated by the presence of condensible vapors and fog. It is from casinghead gas that most of natural-gas gasoline is recovered, a most important by-product of the industry.

APPARATUS FOR OBSERVATION OF THERMAL EXPANSION OF REFRACTORIES FROM 20 TO 1800° C.

THE increasing use at high temperatures of fire-clay refractories and special refractories makes it desirable to add to the present knowledge on the expansion behavior of these materials at elevated temperatures. The bureau has accord-

ingly undertaken a study of the thermal expansion or contraction of a number of refractory materials from 20° to 1800° C., or in the case where softening occurs before reaching 1800° C., to the maximum temperature possible.

The desired temperatures are supplied by a high frequency induction furnace having a hollow cylindrical core of graphite 6 x 12 x ½ in., in which the heat is generated by induced current. The ends of the graphite cylinder are closed as much as possible to prevent oxidation of the graphite which proceeds rapidly at high temperatures. Specimens approximately 6 in. long and 1 in. in cross section are set on end within a muffle, 3 in. in diameter, prepared from zirconium silicate. It was found by experiment that all of the special refractories, except graphite, available for use as part of a set-up within the furnace, proved unsatisfactory because of softening or cracking. Graphite also has a uniform and comparatively low rate of thermal expansion throughout the range of temperature used in this work. Shapes prepared from graphite are used, therefore, as the table on which the specimen stands, as well as for transmitting the linear movement of the specimen to a micrometer dial. A piece of tungsten metal, 1 in. square and .015 in. thick, is placed between each end of the specimen and the graphite pieces to prevent reactions occurring at high temperatures between a specimen and the graphite. The temperature of the zone immediately surrounding the specimen is obtained by means of two thermocouples, inserted through the bottom of the furnace, and placed so that one is near the top and the other near the bottom of the specimen. The thermocouples are removed at approximately 1400° C. and temperatures thereafter up to 1800° C. are obtained by means of an optical pyrometer sighted on the bottom of a graphite tube approximately ¼ in. from one side of the specimen. A micrometer dial fastened by an adjustable holder to a rack, having legs of fused quartz tubing, records the movement of the specimen as well as the movement of the table on which the specimen rests and the system which transmits this movement to the dial. Correction, to take care of the expansion of the system, was determined by observing the movements of materials of known expansion. The difference between the total recorded movement and the known expan-

sion was taken as the correction necessary at any chosen temperature. Fused quartz was used for this work up to 1100° C. and the correction curve extrapolated from 1100° to 1800° C. The latter part of the curve was also checked by expansion observations on a specimen of graphite.

Data with this apparatus have been obtained up to the present on periclase, graphite, and mullite from 20° to 1800° C.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

PLASTICITY AND SOLVATION OF CELLULOSE ESTERS.[1]

By S. E. Sheppard, E. K. Carver, and R. C. Houck.

NUMEROUS theories are reviewed which explain why some substances are better solvents for cellulose esters than others, and especially why mixtures of solvents are so often better than the pure solvents.

Hildebrand's polar—non-polar theory is applied with certain amplifications to cellulose acetate sols in alcohol—chloroform mixtures containing varying amounts of water. The results as shown by the curves are in good agreemene with the theory. The relation of the composition of tht solvent to the viscosity was studied.

THE FALLING SPHERE VISCOMETER AND PLASTICITY MEASUREMENTS.[2]

By H. E. Phipps.

AN investigation was made to determine whether or not the falling sphere viscometer could be used as a plastometer. A series of 1/8 inch spheres of different densities were used and plasticity curves were obtained with cellulose acetate solution. The shearing force applied by the different spheres varied from 10 to 600 dynes per cm^2. These curves did not agree entirely with those obtained with the Bingham and Murray plastometer, because of a difference in the type of flow of the plastic substance in the two instruments. The falling sphere instrument can be used to determine plasticity where present at low rates of shear.

* Communicated by the Director.

[1] Communication No. 316 from the Kodak Research Laboratories and published in *Colloid Symposium Monograph* 5: 243. 1927.

[2] Communication No. 317 from the Kodak Research Laboratories and published in *Colloid Symposium Monograph* 5: 259. 1927.

MOLECULAR ORIENTATION AT SURFACES OF SOLIDS. II. THE WORK OF ADHESION OF THE SATURATED FATTY ACIDS FOR WATER.[3]

By A. H. Nietz.

WHEN work of adhesion of the fatty acids is plotted against number of carbon atoms, the adhesional work shows a marked minimum in the neighborhood of 12 to 14 carbon atoms, beyond which there is a very pronounced increase.

The alternating effect shown by odd and even acids is very marked, the odd acids showing two enantiotropic forms. The β odd and even acids lie on a single smooth curve, the α odd modifications showing alternating higher values.

The alternation and two sets of values for α and β odd acids are attributed to differences in crystal structure.

The general trend of the curve for adhesional work against number of carbon atoms is considered as partly due to the general nature of the adhesional energy-temperature relations and partly to the mechanical effects of the length of the carbon chain.

THE DEPENDENCE OF THE RESOLVING POWER OF A PHOTOGRAPHIC MATERIAL UPON THE CONTRAST IN THE OBJECT[4]

By O. Sandvik

The resolving power of a photographic material may be defined qualitatively as the ability to show fine detail in the picture. It is defined numerically as the number of lines and spaces per millimeter which it resolves. This definition, however, is rather inadequate since resolving power depends on many factors, such as the ratio of the width of the line to the width of the space, the color temperature of the light image, or the wave-length where monochromatic radiation is in question, and the relative contrast in the subject.

The present paper gives some results of an experimental investigation of the dependence of resolving power upon the relative contrast in the test object, where relative contrast is

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[3] Communication No. 323 from the Kodak Research Laboratories and published in *J. Phys. Chem.* **32**: 620. 1928.

[4] Communication No. 334 from the Kodak Research Laboratories and published in *J. Opt. Soc. Amer.* *16*: 244. 1928.

defined as the ratio of the photographic intensities of two adjacent small areas to be resolved.

The method of investigation was to photograph in a reducing camera a series of parallel line test objects differing only in relative contrast, and by microscopic examination of the developed photographic images to determine the maximum resolving power for the respective objects.

The results show that the resolution changes very rapidly with contrast at low contrast values. Thus, with no resolution at unit contrast, the resolving power reaches approximately 65 per cent. of its maximum value for a test object density of 0.5, that is, a transmission through the opaque spaces of 31.5 per cent. or a relative contrast of 3.17; and 87 per cent. of its maximum value when the test object density is 1.0, transmission 10 per cent. and relative contrast is 10. The maximum value of resolving power is reached when the test object has a relative contrast of approximately 100 to 200.

LIGHT FILTERS FOR THE ISOLATION OF NARROW SPECTRAL REGIONS[5]

By L. A. Jones

Data are given relative to a series of light filters by means of which relative narrow bands of radiation may be isolated. These bands are spaced through the region from 300 to 900μ. Dyed gelatin, colored glass, and solutions of stable inorganic salts are used in the construction of these filters.

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[5] Communication No. 335 from the Kodak Research Laboratories and published in *J. Opt. Soc. Amer. 16*: 259. 1928.

The Disappearance of Gases into Glass under the Action of the Electric Discharge. JAMES TAYLOR. (*Nature*, May 5, 1928.) Sodium passes through glass by the action of the electric discharge. In the present experiment the author produced positive ions in several gases at low pressures. By the application of an electric field these ions were brought to the inner surface of a thin-walled bulb of soda glass immersed in molten sodium nitrate after having been well baked out. The electric current traversing the walls of the bulb and the disappearance of the gas were measured concurrently. With hydrogen, oxygen and nitrogen direct proportionality was found between the quantity of gas that disappeared from within the tube and the quantity of electricity that traversed its walls. "For hydrogen, every electron charge passed involves the disappearance of one hydrogen molecule. For oxygen and nitrogen, every two electron charges passed involves the disappearance of one atom of oxygen or nitrogen respectively. For helium a current flowed but no disappearance of gas took place." This result with helium precludes the possibility of attributing the disappearance of the gases to accelerated diffusion, for in that case "helium should pass through about twenty times as quickly as hydrogen."

In view of his finding both glass and quartz to have considerable conductivity of an electrolytic nature at the temperature of the experiment the author assigns the disappearance of the gas to electrolytic decomposition of the glass. In the case of hydrogen water is probably formed that goes well into the thickness of the wall.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY AND SOILS *

THE SPECTROPHOTOMETRIC EVALUATION OF MIXTURES OF METHYLENE BLUE AND TRIMETHYL THIONIN.[1]

By Walter C. Holmes.

[ABSTRACT.]

SPECTROPHOTOMETRIC analysis affords the most convenient means for distinguishing between methylene blue and trimethyl thionin, and for determining the relative proportions in which the dyes are present in a mixture. The methods depend upon the determination of an "absorption ratio." Suitable ratios for the purpose are those of the extinction coefficients at 640 μ to those at 670 μ in solutions containing 50 per cent. by volume of alcohol or of acetic acid. Ratio values are given for eleven mixtures with each solvent, and a graph is plotted from these data. It was found that ratio values were but little affected by moderate variations in hydrogen ion concentration, dye concentration, or neutral salt concentration.

MONOCHROMATIC LIGHT FILTERS FOR THE VISIBLE SPECTRUM.[2]

By Walter C. Holmes.

[ABSTRACT.]

FORMULÆ are given for nine light filters in the visible spectrum between the range of 450 and 700 μ. The filters are aqueous solutions containing copper sulphate together with various dyes, in such proportions as afford approximately 4 per cent. light transmission in 2 cm. layers.

* Communicated by the Chief of the Bureau.

[1] Published in *Stain Technology*, 3: 45–48, April, 1928.

[2] Published in *American Dyestuff Reporter*, Jan. 23, 1928, pp. 31–32.

FUMIGATION OF STORED-PRODUCT INSECTS WITH CERTAIN ALKYL AND ALKYLENE FORMATES.[3]

By R. T. Cotton and R. C. Roark.

[ABSTRACT.]

THE vapors of methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, isoamyl, and allyl formates were tested against rice weevils, clothes moths, carpet beetles, and furniture beetles. All were toxic to these insects. None of the formates tested had an adverse effect upon the germination of wheat. All these formates, except the methyl and ethyl formates, can be made free from fire hazard by the addition of carbon tetrachloride to the extent of from 60 to 75 per cent. by volume of the mixture.

FUMIGATION TESTS WITH CERTAIN ALIPHATIC CHLORIDES.[4]

By R. C. Roark.

[ABSTRACT.]

TWENTY-ONE aliphatic chlorides were tested against rice weevils in flasks half filled with wheat, and against larvæ of the clothes moth, black carpet beetle, and furniture beetle in a 500-cubic foot fumigating vault. It was found that several of the chlorides possess toxicity to stored product insects. From the standpoint of availability, cost, effectiveness and freedom from fire hazard ethylene dichloride in a mixture of 3 volumes of ethylene dichloride to 1 of carbon tetrachloride appears to be the most promising as a general fumingant. Although more toxic than ethylene dichloride, tert-butyl chloride requires a larger proportion of carbon tetrachloride to render it free from fire hazard and cannot be used in metal-lined vaults owing to its tendency to break down and attack the metal. Trichloroethylene is non-inflammable and shows considerable toxicity in vault fumigation at temperatures of 80° F. or over. None of the materials injured the germination of wheat.

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[3] Published in *Ind. and Eng. Chem.*, **20**: 380–382, April, 1928.

[4] Published in *J. of Economic Entomology*, **21**: 135–142, Feb. 1928.

BIOLOGICAL VALUES OF CERTAIN TYPES OF SEA FOOD. II. VITAMINS IN OYSTERS (OSTREA VIRGINICA).[5]

By D. Breese Jones, J. C. Murphy, and E. M. Nelson.

[ABSTRACT.]

FRESH Chesapeake oysters were frozen, ground, and fed to albino rats. The experiment showed that oysters are a good source of vitamins A, B, and D.

Two grams (0.32 gram on a dry basis) of oysters furnished sufficient vitamin A to cure rats of xerophthalmia. Tests made by the curative method showed that 3.5 grams (0.56 gram dry basis) of oysters contained nearly enough vitamin B to supply the needs of young rats. For long-continued normal growth, however, a little more than 5 grams (0.8 gram dry basis) was required. Five grams of oysters given to rachitic rats daily for 10 days induced slight calcification of the long bones, comparable with that produced in the same length of time by 4 mg. of good cod liver oil. The same quantity of oysters induced about half calcification in 15 days and complete calcification of the rachitic metaphyses in 20 days.

Oysters were found deficient in the factor required for reproduction and rearing of young.

Dehydration at 40° C. under reduced pressure (10 to 15 mm.) inactivated vitamins A and B in oysters.

THE PRODUCTION OF GLUCONIC ACID BY THE PENICILLIUM LUTEUM-PURPUROGENUM GROUP. II. SOME OPTIMAL CONDITIONS FOR ACID FORMATION.[6]

By Horace T. Herrick and Orville E. May.

[ABSTRACT.]

EXPERIMENTS were conducted to determine the effects of temperature, concentration of glucose, and inorganic nutrient media on the production of acid by the *Penicillium luteum-purpurogenum* group when cultured on glucose solutions.

It was found that 25 degrees is the temperature most favorable for the formation of acid.

Good percentage yields of acid were obtained from both

[5] Published in *Ind. and Eng. Chem.*, **20**: 205–219, Feb. 1928.

[6] Published in *J. of Biological Chem.*, **77**: 185–195, April, 1928.

the 20 per cent. and the 25 per cent. glucose solutions. The actual quantity of acid, however, was somewhat larger with the 25 per cent. solution.

In the search for the inorganic salt solution most efficient as a nutrient, the effects of different concentrations of magnesium phosphorus, potassium, and nitrogen were determined. On the basis of the data obtained a standard nutrient salt solution of the following composition was prepared:

	Gm. per L. of glucose solution.
$MgSO_4.7H_2O$	0.25 (0.00245% Mg, 0.00325% S.)
KCl	0.05 (0.0026% K)
Na_2HPO_4	0.1 (0.00086% P)
$NaNO_3$	1.0 (0.016% N)

It was found that when ammonium salts were used as a source of nitrogen the production of acid was greatly inhibited although the growth of the organism was normal.

THE DETERMINATION OF SUGARS IN TANNING MATERIALS.[7]

By I. D. Clarke and R. W. Frey.

[ABSTRACT.]

A CRITICAL study is presented on the sugar content, or Fehling's-reducing-power, of a variety of tannin raw materials and extracts. A modification of the method of the American Leather Chemists Association for the determination of sugar in leather is used. It is shown that the effect of the time of hydrolysis upon the sugar yield depends upon the material being examined. Extensive data are given on the lead, phosphate, and acetate content and the effective acidity, or hydrogen ion concentration, at the several stages in the determination. Some preliminary results are given on the use of baker's yeast in determining fermentable sugars, which results suggest interesting possibilities in such a procedure for determining significant differences in the nature of the sugars in various tanning materials. Proposed methods for the determination of total sugars, reducing sugars, non-fermentable sugars, and fermentable sugars in tanning materials and extracts are outlined in detail.

[7] Published in *J. Amer. Leather Chemists Assoc.*, **23**: 91–108, March, 1928.

STUDIES ON GOSSYPOL.
III. OXIDATION OF GOSSYPOL.[8]

By E. P. Clark.

[ABSTRACT.]

UPON oxidation of gossypol with alkaline permanganate, formic, acetic, and isobutyric acids were identified as reaction products. The quantity of each acid formed was determined. The quantity of isobutyric acid obtained was equal to 92.1 per cent. of the quantity required by theory it if is assumed that 1 mol of gossypol yielded 1 mol of acid. Under the conditions of the experiment the presence of isobutyric acid as a decomposition product of gossypol indicates the probable presence in the gossypol molecule of a side chain consisting of at least the isobutyl group.

[8] Published in *J. of Biol. Chem.*, **77**: 81–87, April, 1928.

A Note on Corona at High Humidity. A. W. SIMON. (*Proc. Nat. Acad. Sciences*, March, 1928.) The experiments were made for the Tennessee Coal, Iron and Railroad Co., Birmingham. A series of "parallel copper wires equally spaced and hung parallel to and equidistant from two parallel steel plates with rounded edges" was maintained at negative voltages by connection with a synchronous rectifier. Observations on the corona had been made previous to December 12, 1927. Heavy rain fell thereafter until December 15, and the observations later described were made while the rain was falling. As the apparatus was near an open window the relative humidity was not far from 100 per cent. "Whereas ordinarily, as the voltage was gradually raised, heavy visual corona appeared and persisted up to arc-over, on these two days no corona was visible between the plates, and the current passing from the wires to the plates was enormously reduced. Moreover, on attempting to raise the voltage between the plates, a point was soon reached where a series of intermittent sparks passed across between the electrodes." These sparks appeared at several places simultaneously and grew more numerous and intense as the voltage was raised until a flaming arc appeared. On an ordinary day 55 k.v were requisite for the production of an arc discharge but 35 kv. sufficed on a rainy day. The maximum current before the formation of the arc was more than 20 times as large on a dry day as on a wet one. The change is attributed to the loss of mobility of negative ions in air of high humidity. Elster and Geitel many years ago found that a fog greatly reduces the mobility of gas ions.

When the wires are positive instead of negative with respect to the plates "the corona current flow is greatly reduced and spark discharge sets in at a relatively low voltage even on dry days, so that the action of negative wires on wet days was similar to the action of positive wires on dry days.

G. F. S.

NOTES FROM U. S. BUREAU OF MINES.*

GILSONITE, A DIFFERENT SORT OF MINERAL.

GILSONITE, one of the world's oddest minerals, is mined only in the State of Utah. It is a brilliant, black, asphaltic substance, and is used in the manufacture of varnish, paint, electrical insulation, inks, telephone mouthpieces, electric switch handles, and knobs and buttons of various kinds. The transportation of gilsonite to the consuming public is started over one of the steepest and most crooked railroads in the world, which crosses the Book Cliffs at Baxter Pass at an elevation of 8,437 feet, trains actually traveling 24 miles between points only 6 miles distant by air line.

Gilsonite was discovered in the Ashley Valley in the Uintah Basin, Utah, several years after the first white men settled in the valley in 1878, states W. J. Fene, associate mining engineer, United States Bureau of Mines, in a report just issued. The settlers discovered veins of a brilliant black substance in various parts of the basin. At first this substance was thought to be a variety of coal. When burned, however, it gave off large quantities of dense black smoke with a peculiar odor and instead of reducing to ashes the material melted and drew out into tarlike threads.

The first discovery was probably made in 1862 at what was then called Culmer vein, several miles south of the present site of the town of Myton in Duchesne County.

A study of the substance was made by Professor W. P. Parker. He found that it was a member of the asphalt group and, as it was discovered on the Uintah Indian Reservation, he called it "Uintaite." Samuel H. Gilson became interested in these deposits and spent many years in his efforts to find a market for the Uintaite. His enthusiasm was regarded as more or less wasted by the people of the vicinity and the term "gilsonite" was locally applied to the Uintaite. When Gilson's

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efforts finally developed a market the name gilsonite had become firmly attached to this substance and it is now so known throughout the world.

After more or less successful exploitation of the deposits, involving the hauling of the ore as far as 125 miles to a railroad, in 1902, the demand for the material became so great that better methods of placing it on the market became necessary. The Black Dragon vein was developed, and by 1904 enough ore was accrued to warrant the construction of the Uintah Railway connecting the Dragon Mine with the Denver and Rio Grande Railroad at Mack, Colorado.

Gilsonite occurs in the veins in a solid homogeneous mass and breaks with a conchoidal fracture. Even in the minutest pieces the brilliant fracture is preserved. Long exposure to the weather causes it to lose this brilliant black luster and it becomes dull and black. Occasionally it has a fine columnar structure at right angles to the walls. This is called "pencilated" ore and is frequently found on both sides of the vein. The veins outcrop on hilltops but elsewhere the ore is covered with 15 feet or more of soil.

The surface ore melts at about 400 degrees and is used principally as a saturant of felt in the manufacture of roof and floor coverings. It is generally designated as White Label ore and with increasing depth it gradually becomes better in grade and is termed "select" grade about 50 feet beneath the surface at the Rainbow mine; but in places north of the White River "select" material is not found until a depth of 300 to 500 feet is reached. Select ore will melt at 275 degrees F. and is used in the manufacture of high-grade paints, varnishes, and electric insulation. Although gilsonite lacks any elastic properties, it makes a varnish whose elasticity is remarkable. A thin piece of tin coated with good gilsonite varnish may be bent repeatedly without the coating being cracked.

Gilsonite is closely related to wurtzilite or elaterite and to ozocerite, which is also found in the Uintah Basin. A kindred hydrocarbon, grahamite, is found in Oklahoma. The specific gravity of gilsonite is 1.035, its hardness is 2, and the streak on a porcelain plate is brown. It is exceedingly brittle and during mining gives off clouds of chocolate brown dust which

softens under the heat of the body and is very penetrating to the skin. It is insoluble in water and is removed from the body with difficulty. It is not affected by acids but is soluble in alcohol, turpentine, carbon bisulphite, heavy oils, and fats.

The Uintah Basin, an area of some 15,000 square miles, contains a storehouse of asphaltum, asphaltic sandstone, and oil shale so large that expressed in figures it is staggering. It is estimated that one mile of the Cowboy vein alone, in the widest place, contains about 316,800 tons for each 100 feet in depth, so that the supply of gilsonite seems almost inexhaustible.

Various theories have been advanced as to the formation of these veins. The most plausible theory appears to be in this great synclinal basin gigantic cracks were formed in the brittle and non-elastic sandstone measures of the Uintah formation. Later due to heat the oily matter in these carbonaceous measures was distilled from the underlying Green River shales and deposited in these cracks.

The ore found near the surface contains foreign matter, mostly silica, which renders it unfit for the best trade. It was formerly the practice to leave in the ground as pillars much of this surface ore, but recently the use of this quality of gilsonite for the saturation of felt has increased until it comprises one-half of the gilsonite ore shipped. The growth of foreign use of gilsonite has increased until one-fifth of the ore mined is consumed outside of the United States. The demand for gilsonite in England, France, Germany, Italy, Holland, Belgium, and Japan is steadily increasing.

A very small amount of foreign matter in a shipment of select ore will render it unsuitable for varnish so that the utmost care must be taken to prevent chips of rock or grains of sand from getting into the high-grade ore.

The mining of gilsonite, unlike that of coal or other ores, requires no elaborate surface plants. The ore outcrops at the surface where mining is started and progresses downward, all of the ore of the vein being removed. The gilsonite ore does not have to be prepared and, as it is sacked and made ready for shipment in the mine, the only loading equipment necessary is a platform from which the sacks of ore are transferred from the mine car to railroad cars.

RECOVERY OF RADIUM, VANADIUM, AND URANIUM FROM CARNOTITE.

THE use of a modified nitric acid method for the recovery of radium from carnotite tailings, from which the vanadium has been extracted is suggested by the Bureau of Mines, to prevent the loss of the radium content being wasted in present practice.

The carnotite ores of Colorado and Utah were the chief source of radium for many years. In the fall of 1922 news of the very rich deposits of radium ore discovered in the Belgian Congo caused almost complete cessation of domestic production. The Congo ore contains pitchblende and a number of alteration products, including the newly identified minerals bequerelite, curite, kasolite, stasite, and dewindite. Reports indicate that a considerable amount of ore containing over 50 per cent. uranium oxide has been produced. The price of radium has been held at $70 per milligram. Extraction of radium from carnotite by the usual methods does not appear to be profitable at that price. With one exception, all American firms ceased production after their accumulated stocks of ore had been treated. One company, which continued to treat carnotite for several years, has recently shut down its plant.

Carnotite contains the valuable element, vanadium, which is not present in the Congo ore. The recovery of vanadium is an important factor in the cost of extracting radium from carnotite, and under favorable conditions carnotite can be profitably treated for the vanadium alone. Vanadiferous sandstones are found ranging all the way from roscoelite (vanadium mica), containing little or no uranium, to a high-uranium and low-vanadium carnotite. Ores containing 2 per cent. or more uranium oxide are classed as radium ore and are sold on the basis of the uranium content, which is proportional to the radium content. Only in exceptional cases have ores been evaluated on the basis of both the radium and vanadium contents, although the presence of vanadium has undoubtedly influenced the price of radium ore.

Since the advent of radium from Congo ore, a large quantity of carnotite has been treated for the vanadium alone, the radium being discarded with the tailings. Since the entire cost

of mining, transportation, and milling the ore is thus covered by the value of the vanadium, it seems advisable to ascertain whether the radium and uranium can not also be recovered at a profit, or at least saved in such a concentrated form as to be available when market conditions justify further refining.

Present methods of extracting vanadium from carnotite leave the radium as a fine precipitate in the tailings. The water used to flush these tailings away from the plant and the subsequent weathering may easily disperse the radium-bearing slime beyond possibility of recovery. If, however, the tailings are deslimed and the slimes dewatered and stored, then the radium will be saved in a concentrated condition suitable for subsequent refining; this can be done at a cost which is an insignificant fraction of the former, and probable future, value of such a concentrate. There is also a limited market for such material in the manufacture of so-called medecinal radioactive preparations, which, though reported of doubtful therapeutic value, might better be made from a discarded tailing than from a virgin ore having a still lower radium content.

LUMINOUS PRESSURE WAVES.

PHOTOGRAPHY of the phenomena taking place when a cartridge of dynamite is detonated has shown the existence of luminous waves propagated at high speed in the air surrounding the explosive. It was at first thought by the Bureau of Mines' investigators that these waves were merely reacting gases projected from the explosive, but further work in which the air around the stick has been replaced by hydrogen or carbon dioxide has made it seem probable that these are really pressure waves at such high temperatures that the gas actually radiates in the visible region of the spectrum. The work is part of a program of investigation of the sensitivity of explosives to detonation by influence.

INDENE AND STYRENE.

IN the course of a study by the Organic Chemical Laboratory of the Bureau of Mines of the cause of service gas meter

stoppages it developed that the main cause of the trouble was gum formation from indene and styrene. These compounds are always present in manufactured gas. In freshly made gas they are very volatile and readily carried in the gas stream, but on standing in contact with other gas constituents they tend to "polymerize" or form gums. Gums are thus formed in house meters, making removal of these for cleaning necessary.

A recent survey of the gas industry develops that there are 8 million pounds per year of styrene and twice that amount of indene available if completely removed from the gas. These compounds could be used in the manufacture of plastics. Styrene could be used in the manufacture of perfumes and possibly also in rubber manufacture. It is suggested that here is a field for development of industrial values in these substances which are now admittedly industrial nuisances.

FERROUS OXIDE A METALLURGICAL MYSTERY.

The Pacific Experiment Station of the Bureau of Mines, Berkeley, Calif., in its work on the determination of physical and chemical properties of the oxides of metallurgically important substances, has encountered the problem of preparing pure ferrous oxide. It seems to have been prepared pure by previous investigators only in minute amounts of less than 1/10 gm., whereas samples of several pounds are desired for the usual determinations of specific heats, heats of formation, etc. The oxide is metastable below 500° or 600° C., and must be prepared above and rapidly chilled through this range, even to produce relatively impure material. A common method of preparation has attempted to reduce magnetite by metallic iron. Experiments carried out in a specially designed high-frequency induction furnace of vacuum type, and provided with a specially efficient means of chilling the product, showed that repeated treatments of fused iron oxides with pure iron between the melting point of the oxide and that of the iron, consistently gave only about 85 per cent. limiting purity. This constitution seems to be a steady or equilibrium condition, and the proof that such limits exist has important bearing on certain problems involving ferrous oxide, not only

in connection with the metallurgy of iron, but also with studies of the condition of copper-smelter, slags, and mattes.

THE EXPLOSIBILITY OF VARIOUS COALS.

DURING the past fifteen years the Bureau of Mines, at its Experimental Mine, has tested mine-sized dust prepared from coal taken from 29 different mines in different parts of the country. These range in composition from the anthracites of Eastern Pennsylvania to the high volatile coals of Utah and Wyoming. The amount of incombustible material required in a mixture to prevent propagation of an explosion under standard propagation test conditions was determined for each coal. It was found that 20 per cent. was sufficient for a coal whose ratio of volatile to total combustible was 0.15 but the quantity increased rapidly with increasing ratio and 61 per cent. was required with coals whose ratio was 0.23. There was then no further increase until ratio 0.40 was passed; that is, a coal having a ratio of 0.40 required 61 per cent. incombustible in the mixture the same as a coal of ratio 0.23. Beyond ratio 0.40 there was a slow increase and 70 per cent. incombustible was required for coals whose ratio was 0.50. It is felt that these limits are known with sufficient accuracy to justify applying them to any coal not tested in the Experimental Mine. Composition is one of six factors which influence the explosibility of coal dust and a paper summarizing the present knowledge of all six is in preparation.

Reflection of Electrons by a Crystal of Nickel. C. J. DAVISSON AND L. H. GERMER. (*Proc. Nat. Acad. Sciences*, April, 1928.) This report continues an investigation the results of which were published in 1927. A crystal of nickel is regarded as made up of small cubes piled one upon the other. The surface on which the electrons impinged was obtained by slicing off a corner of the crystal by a plane at right angles to a diagonal of a cube. Thus an equilateral triangle was produced. The plane in which the electrons were incident was perpendicular to the triangle and passed through a line drawn from its center to one of its apexes. Rows of atoms of the metal lie in the triangle and parallel to it. "We find that under certain conditions a sharply defined beam of scattered electrons issues from the crystal in the direction of regular reflection. This occurs whenever the speed of the incident electrons is comprised within any of certain ranges which change in location as the angle of incidence is varied. Within each of these ranges there is an optimum speed at which the intensity of the reflected beam attains a maximum." Diagrams are shown in which the intensity of the beam of scattered electrons is displayed in different directions. With a proper bombarding voltage the curves of intensity possess very sharp maxima when the reflected beam makes the same angle with the perpendicular to the triangle as the incident beam. "The angles of incidence and reflection are in all cases the same to within half a degree by our scale readings, and this is within the limit of uncertainty of the measurements."

The discovery of regular reflection of electrons from the face of a crystal is of great significance at this time when the wave theory of matter is under discussion. If a beam of electrons and a beam of radiation are reflected in the same way the cause of this common effect is to be sought in the common structure of the two beams.

G. F. S.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, June 6, 1928.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, June 6, 1928.

DOCTOR GEORGE S. CRAMPTON, *in the Chair.*

The following report was presented for final action:

No. 2872: Pendulum Hardness Tester.

The subject of this investigation includes a new method of measuring the hardness of materials and a new form of apparatus by the use of which the measurement can be carried out. While the method of making an indentation in the surface of the material under test is similar to that employed in other hardness testers the manner of making the indentation and of measuring its amount are new.

The indentation is made by a steel ball 1 mm. in diameter to which a known weight is applied. This weight consists of an inverted U-shaped piece of metal which carries the ball in a central chuck, the proper adjustment being such that the center of gravity of the weight nearly coincides with the center of the ball.

This constitutes a compound pendulum having a large moment of inertia and a very short length which is adjusted so as to bring the period of oscillation to ten seconds for a single swing, when the ball rests upon a horizontal glass surface.

When the instrument is set upon the surface of a softer material the swinging of the pendulum is affected in two ways: first, its swings are dampened; second, its period of swing is shortened. These two effects constitute two distinct means of measuring hardness. The dampening effect gives data for the Scale Hardness Test and the change in the period of oscillation gives data for the Time Test. The Time Test may be described as a measure of indentation hardness and the Scale Hardness Test is a measure of resistance to flow.

The recommendation to award the Edward Longstreth Medal to Mr. Edward G. Herbert of Levenshulme, England, in consideration of his technical ability in the development of this unique method and the instrument for putting it into effect and the contribution he has made to the general knowledge of the subject of the hardness of metals, was adopted.

The following reports were presented for first reading:

No. 2875: Ruths' Steam Accumulator.

No. 2893: Gas Carburizing Apparatus.

GEO. A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, June 13, 1928.*)

RESIDENT MEMBERSHIP.

COLONEL JAMES H. M. ANDREWS, Assistant to the President, Philadelphia Rapid Transit Company, Mitten Building, Broad and Locust Streets. For mailing: 7208 Lincoln Drive, Philadelphia, Pa.

MR. EDWARD W. BURNSHAW, JR., Automotive Business, 245 North Broad Street, Philadelphia, Pa.

MR. A. LESLIE LAMBERT, Secretary, Chief Engineer, Heintz Manufacturing Company, Front and Olney Avenue, Philadelphia, Pa.

MR. DAVID F. REILLY, Medical student, 235 North Eighteenth Street, Philadelphia, Pa. For mailing: 617 Main Street, Dickson City, Pa.

NON-RESIDENT MEMBERSHIP.

MR. HERBERT A. ERF, Acoustical Engineer, 407 Permanent Homes Building. For mailing: 11851 Lake Avenue, Suite 21, Lakewood, Cleveland, Ohio.

DR. LEONARD B. LOEB, Associate Professor of Physics, Department of Physics, University of California, Berkeley, California.

DR. FRANK N. SPELLER, Director—Department of Metallurgy and Research, National Tube Company, 1810 Frick Building, Pittsburgh, Pa.

CHANGES OF ADDRESS.

LUCIUS B. ANDRUS, Esq., Indianapolis Athletic Club, Indianapolis, Indiana.

MR. JOSEPH S. BENNETT, 3D, 274 Forrest Road, Merion, Pa.

MR. ROLAND B. DAY, The Day Petroleum Corporation, 30 Church Street, New York City.

MR. WILLIAM DUBLIER, Dublier Condenser Corporation, 10 East Forty-third Street, New York City.

MR. HUGH S. GORDON, Tati Company, Ltd., Francistown, British Bechuanaland, South Africa.

MR. WILLIAM STEELL JACKSON, 1011 Chestnut Street, Philadelphia, Pa.

MR. CHARLES F. KELLERS, 759 West Washington Avenue, Jackson, Michigan.

MR. W. E. MOORE, President W. E. Moore and Company, Engineers, Foot of Thirty-second Street and Putney Way, P. O. Box 1125, Pittsburgh, Pa.

DR. ALFRED OBERLE, 842 New York Life Building, Kansas City, Missouri.

CAPTAIN E. R. WOOD, JR., Room 607 Provident Trust Building, Seventeenth and Chestnut Streets, Philadelphia, Pa.

MR. W. M. KERR, Packard Building, Fifteenth and Chestnut Streets, Philadelphia, Pa.

LT.-COL. CHESTER LICHTENBERG, 300 Strathmore Road, Brookline, Upper Darby, Pa.

MR. FRANK S. MACGREGOR, Twenty-third Floor, 2 Park Avenue, New York City.

MR. F. M. MURPHY, 209 South New Hampshire Avenue, In care of J. V. Lehigh, Esq., Los Angeles, California.

MR. W. S. MURRAY, 369 Lexington Avenue, New York City.

DR. SAMUEL E. POND, Woods Hole, Mass.

NECROLOGY.

Mr. Thomas J. Dolan, Villa Nova, Pa.

Dr. I. P. Lihme, Cleveland, Ohio.

LIBRARY NOTES.

Recent Additions

ABEGG'S Handbuch der anorganischen Chemie. Vierter Band, dritte Abteilung, erster Teil. 1928.
American Electrochemical Society. Transactions 1927. Volume 51. 1928.
CHAMBERLAIN, JOSEPH SCUDDER. A Textbook of Organic Chemistry. 1928.
CREW, HENRY. The Rise of Modern Physics. 1928.
DAVIS, A. H., AND G. W. C. KAYE. The Acoustics of Buildings. 1927.
GOLDSCHMIDT, VICTOR, AND SAMUEL G. GORDON. Crystallographic Tables for the Determinations of Minerals. 1928.
History of Science Society. Sir Isaac Newton, 1727–1927: a Bicentenary Evaluation of his Work. 1928.
KEEN, R. Wireless Direction Finding and Directional Reception. Second enlarged edition. 1927.
MACINTIRE, H. J. Handbook of Mechanical Refrigeration. 1928.
MARSHALL, C. F. DENDY. Two Essays in Early Locomotive History. 1928.
MOTTELAY, P. FLEURY. Life and Work of Sir Hiram Maxim. 1920.
OLLIVER, C. W. The A.C. Commutator Motor. 1927.
PALMER, L. S. Wireless Principles and Practice. 1928.
POMEY, J. B. Cours d'Électricité Théorique. Tome I. 1914.
QUAERIS, Q. M., AND OTHERS. Notre Misère Scientifique: ses Causes—ses Remèdes. L'Appel du Roi. 1928.
Society of Chemical Industry. Reports of the Progress of Applied Chemistry. Volume 12, 1927.
TURNBULL, ARCHIBALD DOUGLAS. John Stevens: an Americal Record. 1928.
WALTON, ROBERT P., Editor. A Comprehensive Survey of Starch Chemistry. 1928.
WEISER, HARRY BOYER. The Hydrous Oxides. 1926.
WIEN, W., AND F. HARMS, Editors. Handbuch der Experimentalphysik. Band 19. 1928.
WILCOX, EDGAR A. Electric Heating. 1928.
WILSON, WILLIAM. Electric Control Gear and Industrial Electrification. 1927.

BOOK REVIEWS.

THE CHEMICAL EFFECTS OF ALPHA PARTICLES AND ELECTRONS. By Samuel C. Lind, Ph.D., Director of the School of Chemistry, University of Minnesota. Second (revised and enlarged) edition. American Chemical Society Monograph Series, Number 2. 252 pages, 42 tables, 13 illustrations, cloth, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $5.

That the subject of this volume represents a live and rapidly growing division of experimental and theoretical science, may be realized fully from a comparison of the first and second editions. In the six years which have elapsed between the issuance of the first and second editions sufficient additional information has become available to make this monograph one-half as large again.

Doubtless, there are but few who can realize and appreciate the full significance of these recent discoveries and fewer still who would dare to predict the status of this subject six years from now. As in all branches of scientific investigation many difficulties have been encountered and are being overcome, one by one, by dint of brilliant thought and plenty of hard work.

That the chemical effects of alpha particles and electrons may be investigated with any degree of success a satisfactory source of radiation is imperative. As a source of alpha-particle radiation radium-C and radium-F (polonium) have been utilized to advantage. Yet, their relatively short periods of existence have made impossible any sustained investigation of their chemical effects. Until recently no constant source of electron (beta particle) radiation has been available. However, this problem has been solved ingeniously by Dr. Coolidge of the General Electric Co., who, has developed a tube which will produce electronic radiations of controlled intensity and make them available for experimental purposes. So far the effects produced by this beta ray (particle) radiation have been studied only in a qualitative way. Such phenomena as already observed, indicate that in the near future these rays will play an important part not only chemically but also physiologically and therapeutically.

In studying the chemical effects of these radiations both qualitatively and quantitatively the chemist must adopt a specialized technique already acquired by the physicist who has been studying intensively the physical properties of these radiations for three or four decades.

There seems to be no doubt but what continued investigation in this field will disclose many fascinating problems. Already anomalies in the predicted behavior of the various reactants have been observed and organic compounds of unsuspected constitution evolved.

A very comprehensive perspective of the widespread advances in the field of radiochemistry during the past six years may be obtained from the author's preface to the second edition. The progress accomplished in this sphere has necessitated the addition of seven new chapters and an extensive revision of the others. New discoveries have added support to the theory of reaction mechanism in ionized gases and emphasized the idea of ion clustering. The work of Mund on the development of a general equation for calculating gas ionization by radon in spheres is outstanding. Results obtained in the investigation of the catalytic influence of foreign gases make necessary a broader view on the probability of electron exchange, while the determination of the size of effective ion clusters in different gaseous systems looms up as perhaps the most outstanding problem at the present time.

The first chapter, "Radiochemistry," has been enlarged by a paragraph on the utility of the Einstein law of photochemical equivalence. In addition the author has defined the term radiochemistry, outlined the field embraced by it and shown its relation to that branch of the study known as photochemistry. Chapter two contains a brief outline of radioactivity and some properties of the radiations. Such knowledge concerning the radioactive series of elements is necessary if the reader would have a clear understanding of the controlling factors in the various experiments to be described later. Chapter three deals with the electrical effects produced by the various radiations, alpha, beta, gamma and X-rays and the general characteristics of gaseous ionization. A paragraph

on the relation between beta and gamma rays has been added. Chapter four, "Qualitative radiochemical effects," has been largely rewritten and contains much new material. The author arbitrarily classifies radiochemical investigations under eight headings depending upon the amount of definite knowledge available. A timely paragraph on precautions in sealing radium salts has been inserted. Radium sealed in small tubes for a considerable length of time has caused the tubes to explode with a resultant loss of its valuable contents. A far-reaching disintegration of quartz containers has been reported and pyrex containers also have been found to be unsuitable for radium solutions. Other topics dealt with in this chapter are the luminescence of radium salts, the coloration of glass and minerals, thermo- and photo-phosphorescence and the discharge of color, constant light sums of thermo-phosphorescence, etc. The paragraph on luminescence and phosphorescence produced by radiation is particularly interesting containing as it does an exposition on the preparation and properties of luminous paints. Chapter five deals with chemically quantitative investigations in liquid systems and includes a study of the decomposition of water by radium salts in solution, the formation of hydrogen peroxide in water and reactions produced by penetrating rays. The effects of the penetrating rays have been studied extensively by Kailan and included such things as the decomposition of the alkaline and rare earth iodides, the reduction of ferric sulphate, the inversion of cane sugar, the conversion of nitrobenzaldehyde into nitrobenzoic acid, the action on chloroform and carbon tetrachloride and the oxidation of toluene. In some of these experiments a comparison was made with ultraviolet radiation which produced similar effects one hundred to one thousand times as rapidly. Chapter six contains a description of the first experiments upon the reactions produced by radon. These consisted of the decomposition of carbon monoxide, hydrogen chloride, ammonia, and the decomposition of water as well as the combination of hydrogen and oxygen both dry and moist. Considerable work also has been done on the equilibrium between hydrogen, nitrogen and ammonia. Considered in the light of experimental technique and the application of theoretical knowledge chapter seven is no doubt the most important in the book. It begins with an outline of the historical development of the ionization theory of the chemical effects of corpuscular radiation. This is followed by a paragraph on how to construct and use an alpha-ray bulb, the calculation of ionization from such a bulb and the purification of radon to be used in the bulb. The development of an equation for calculating the average path of alpha particles in a sphere is clearly described. This is followed by an equation for the calculation of ionization of radon in small spheres and a detailed description of Mund's equation for calculating ionization by radon in large spheres. This chapter also contains an exceedingly valuable and comprehensive table giving a comparison of the chemical action and ionization by alpha particles. Chapter eight occupies itself with a development of a general kinetic equation for the action of radon when mixed with gases in small volumes and the application of this equation to experimental results. Chapter nine, "Chemical effect of recoil atoms" corresponds to the latter part of chapter eleven in the first edition. A comparison of the absorption of alpha rays and recoil atoms is made; the latter's general properties, chemical reactions described and the results of later experiments outlined. Chapter ten on additional relationships of the radiochemical effects discusses

the influence of varying the proportions of reactants, the action of alpha rays on pure oxygen, activity of gaseous hydrogen ions, energy utilization of alpha rays in chemical reactions and includes a general discussion of ionic-chemical equivalence. Chapter eleven deals exclusively with what is known as the M/N ratio or the relation of chemical reaction to ionization. Chapters twelve to fifteen inclusive deal with the effects of radiation upon saturated one-component systems, unsaturated one-component systems, oxidation in two-component systems and hydrogenation in two-component systems respectively. An excellent summary of the material is given by the table in chapter seven as mentioned above. Chapter sixteen on the catalytic effect of ions of inert gases deals with some of the more recent investigations in this field. In general, the presence of an inert gas has caused an acceleration in the reaction produced by the radiations. The mechanism of these catalytic ion reactions has been a source of speculation and at present is believed to involve an exchange of electrons between the molecules of inert gas and those of the reactants. A chapter (seventeen) on the chemical effects of electrical discharge in gases is certainly not amiss in a book like this. Investigations in this sphere seem to have been more or less incidental and have resulted in a great variety of phenomena being recorded. The ionization theory has been applied to these electrochemical effects in gases more or less successfully. Chapter eighteen contains an elucidation of the law of photochemical equivalence and a comparison with ionic-chemical equivalence. The relation between the two is striking. So far this book has dealt with the effects produced by the alpha rays colliding with the electrons of the atoms or molecules. However, an occasional alpha particle will collide with the nucleus of the atom and cause a disruption of the latter. The book would not be complete without the last chapter which outlines the research done on the atomic disruption by alpha particles. The author critically examines the results of these investigations which are of comparatively recent origin. The appendix consists of tables giving the decay of radon, conversion factors, ordinary isotopes of the elements, list of radioactive isotopes by groups, Mund's factor for the efficiency of ionization by radon in spheres and a list of papers by the author and his collaborators respectively. The book contains both an index of authors and of subjects.

Dr. Lind has done a splendid piece of work in the rewriting and revision of the first edition of his book. When the abundance of widely scattered and seemly unrelated data concerning this subject is taken into consideration, then it will be realized just how difficult it must have been to evolve a system of classification such as this book embodies.

THEODORE K. CLEVELAND.

THE METHODS OF ORGANIC CHEMISTRY. A LABORATORY MANUAL. By C. W. Porter, T. D. Stewart and G. E. K. Branch, Members of the Faculty of the College of Chemistry in the University of California. iv–311 pages, 8vo., illustrated. Boston, Ginn and Company, 1927. Price, $2.

The authors make very modest claims in regard to the rôle this book is supposed to fill in the study of organic chemistry. They have started out with the expressed intention to prepare an outline providing material for a laboratory course in organic chemistry. When they finished they had a manual which not only students but those doing research will find to be of inestimable value as a

reference volume. This book, which was designed to meet the requirements of either the usual short course in organic preparations, or of a full-year course is composed of five parts. Part I and experiments selected from Part II constitute the subject matter for a half-year course while the system of qualitative analysis as outlined in Part III constitutes material for a second half-year's work. Part IV is a very complete discussion on acids, bases and indicators, while Part V is a description of the methods used in quantitative analysis of organic substances.

Part I, "Mechanical Operations," clearly describes the latest approved technique as applied to experimentation in organic chemistry and is well supplied with illustrations of the necessary apparatus. The first subject dealt with and one of primary importance is distillation. The physical chemistry of vapor pressures of pure liquids and their mixtures has been inserted in order to give the student some idea as to the why and wherefore of such procedure. The process of extraction is treated from the viewpoint of the partition coefficients of solvents and placed upon a more or less quantitative basis. The chapter on the determination of the boiling point includes instructions for the correction of boiling points and a list of constants for some of the more common liquids. The various methods of drying are considered in quite some detail and are accompanied by a table giving the vapor pressures of various drying agents. Other subjects discussed in this first part are filtration, crystallization, sublimation, determination of the melting point and the calibration and use of thermometers. If the student or researcher should desire to apply various other physical methods he will find at the end of the section a bibliography for such methods as optical rotation, absorption spectrum, boiling-point and freezing-point determinations, refractive index, colorimetric and microscopic analysis, magnetic rotation, determination of hydrogen ions, etc.

Part II, "Organic Preparations," starts out with exercises in distillation and crystallization, this is followed by a description of the methods used in qualitatively testing for the elements and includes equations for the principal reactions involved. The remainder of the section describes the preparation of over fifty organic substances involving most of the well-known methods of organic synthesis. A list of questions for review also is included in this section.

Part III, "Class Reactions," is a system of organic qualitative analysis. The authors have divided the organic substances into various classes and described those reactions peculiar to the members of each class. Their method of accomplishing this is very commendable in that they lay particular emphasis upon the probable mechanism of the reactions and the intimate relations between such reactions and the structure of the compounds involved. The whole system is logically laid out and the worker reaches his objective through a process of elimination.

Part IV, "Acids, Bases and Indicators," considers acids and bases from the standpoint of their ionization constants or the extent to which they ionize in solution. The nature of indicators is discussed on a similar basis. The titration of acid and bases and the determination of equivalent weights is dealt with in great detail. A graph is given having hydrogen ion concentration plotted against equivalent weight and clearly shows why one indicator is more suitable than another in a particular titration. Considerable stress is laid upon the possible error in end-point of titration, the percentage error and erratic errors.

Part V, "Quantitative Analysis," contains a description of the well-known methods for quantitatively determining the amount of carbon, hydrogen, oxygen, nitrogen, sulphur, or halogen in organic compounds. Following Part V is a list of over one hundred problems for review. The appendix consists of tables giving the vapor pressures of water and such organic liquids as methyl and ethyl alcohol, ether, acetone, benzene, chloroform, carbon tetrachloride, and carbon bisulphide; a list of the elements with their atomic numbers and weights; the vapor pressure of aqueous potash hydroxide solutions and methods of preparing various indicators and reagents.

The authors have produced a book which is noteworthy for its completeness of detail and clarity of description. The book is something more than an ordinary laboratory manual since it contains much information of value to the advanced student and research chemist. THEODORE K. CLEVELAND.

ELECTRIC CONTROL GEAR AND INDUSTRIAL ELECTRIFICATION. By William Wilson, M.Sc., B.E., M.I.E.E., A.A.I.E.E. xiii–361 pages, 21 x 14 cm., cloth. New York, Oxford University Press, American Branch, 1927. Price, $8.50.

The adaptability of the electric motor drive to any and every kind of machine is now generally accepted as a matter of course. The rise of electric motive-power is due to several independent factors. Next in importance to the motor itself, one of these is the perfecting of the several auxiliaries known as the electric control gear whereby the combinations of contacts which control the passage of current in accordance with a predetermined plan and method of operation are made and broken. For small powers and fixed speeds the matter is a relatively simple one, but with variable speeds, large powers, remote and sometimes automatic control, the problems that arise in providing mechanisms which will perform such functions with certainty demand the closest study on the part of the designer. The author, in presenting an account of the multiplicity of functions of the power-current in the motor circuit and the devices by which they are controlled, has gathered an extensive collection of typical apparatus adapted to a wide variety of applications in which considerable or large quantities of power are consumed.

Since the characteristics of the motors to be controlled and the power which they are required to deliver are leading elements of the subject, the author prefaces the consideration of the various types of control equipment with a brief review of the capabilities and peculiarities of the chief forms of motor employed in industry. That done, the principal topics of the discourse are considered in detail. Among these we have first, chapters on manual starters and controllers, resistance control and multiple-voltage and series-parallel control followed by a chapter on methods and devices employed for starting squirrel-cage and synchronous motors. Solid resistors and liquid rheostats each have a chapter. Those devices which may be classified generally as relay systems and their details are given three chapters with an additional chapter on the methods of laying out the constituent elements of control systems. Electric braking and motor-generator control systems complete the treatment of the details of the control gear.

The subsequent chapters describe the characteristics of the electric operation of factories in general and more specifically the equipment and control apparatus for electric elevators, rolling mill and other mill motors, furnace and mine hoists,

electric cranes, machine tools. Each of these is given a chapter and there is a final chapter on control gear for the operation of machines not included in the classes above mentioned.

Of electric control gear there is already quite a comprehensive literature on American practice but this work deals also in a large measure with the entire installation. On both of the divisions specified in the title, the book contains a large amount of practical data in a convenient form as well for reference as for systematic study of the electric power equipment of factories.

LUCIEN E. PICOLET.

HANDBUCH DER ANORGANISCHEN CHEMIE. By R. Abegg, F. Auerbach and I. Koppel. Band IV, 3, 1 Teil. Die Edelgase, by Dr. Eugen Rabinowitsch. 522 pages, illustrations, 8vo. Leipzig, S. Hirzel, 1928. Paper cover, 45 marks; bound 48 marks.

The series to which this volume belongs has established itself among the foremost treatises on inorganic chemistry. The whole work has been characterized by comprehensiveness and accuracy. The literature has been thoroughly sifted and the data well arranged. The volume in hand has somewhat more than ordinary interest, for some of the romance and tradition of chemistry is involved. The term "noble gases" takes us back to the alchemists and even beyond. The indifference of gold and silver to the common corroding agents was evident and impressive. It might be worth while to speculate on what would have been the reaction of the ancients to platinum. Their inability to melt it and the ease with which it can be alloyed with the baser metals might have been puzzling. The classification in this volume puts the gases of the helium group as the eighth period of the periodic system, but many tables place the series first. The difference is not important. Of all the members of the series, helium interests us most. Recognized originally in the chromosphere of the sun and, for a while, presumed to be an element beyond our reach, it has become quite familiar, and is obtainable in considerable quantities. The United States has, so far as known at the present time, the largest supply, and people in many parts of the country are familiar with the fish-like bag of the dirigibles floated by it. Its production by the disintegration of uranium has also a most important bearing upon the basic principles of chemistry.

As is well known, the first of the series discovered was argon, which had been for a long while overlooked in the air, although present in decidedly appreciable proportion. Its indifference to chemical action made it at the time of its discovery an exception to general elementary rule and earned its name. Krypton, xenon and neon are now also known. Neon has become very familiar from its large use in display signs on account of its strong red emission under electric discharge.

It is to be regretted that Lockyer assumed that the element which gave the bright yellow line near those of sodium was a metal, for the proper name is "helion," but there is little hope of a change generally among chemists. A curious feature of the history of helium is the confusion in the bibliographies that have been published and the fact that there seem to be no definite data as to when and by whom the element was named. The author of this volume ascribes the naming to Lockyer and Frankland, but in 1894, Lockyer said in a

lecture that he coined the name as a laboratory term, presumably to avoid frequent periphrases. In several of the bibliographies of helium the name of Frankland has been improperly joined with that of Lockyer; Janssen also has been given credit which does not seem to belong to him.

It is interesting to compare the volumes of this series with the work that appeared under the authorship of Gmelin. The latter was in its day a monumental contribution to chemistry, and in spite of the vast increase of data and the extensive changes in theory that mark the intervening years, Gmelin's volumes are still worth consulting in many cases.

Concerning the specific character of the volume in hand it is merely necessary to say that it sustains the reputation of its predecessors and presents a splendid study of the chemistry of the curious and important group of gases of indifferent chemical affinity. The publisher has issued it in excellent form with clear, easily read type, good paper and presswork. It constitutes an epoch-making contribution to the literature of inorganic chemistry.

HENRY LEFFMANN.

A COMPREHENSIVE SURVEY OF STARCH CHEMISTRY, Volume 1. Compiled and edited by Robert P. Walton, with numerous collaborators. 360 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $10.

Starch is an interesting carbohydrate. Throughout the vegetable kingdom it occurs very frequently, especially in roots, tubers and seeds. Through its capacity to be converted rapidly and easily into sugars it becomes the basis of a very large number of industries especially the fermentation industries which bring the chemist in contact with problems that are related to society and to conduct. The changes that occur in starch are mostly through the influence of enzymes, those peculiar nitrogenous bodies which have the power to produce a very large amount of chemical action without being themselves exhausted in the process. They are somewhat like the initiators of our modern high explosives. In fact starch itself might be compared to a high explosive, though the products of its explosion are mild forms of energy. The source of starch in the vegetable kingdom has been the subject of a good deal of investigation and some speculation which is based perhaps more upon hope than upon absolute proof. A very simple chemical reaction between carbon dioxide and water resulting in the elimination of oxygen will give us starch, but the problem has been to account for such a reaction inasmuch as it is accompanied by the absorption of energy while the majority of chemical reactions liberate energy. The generally accepted explanation which seems to be well founded, indeed might be considered as proved, is that the energy is that of light. Starch in itself of course does not exhibit any energy, it does not radiate it as radium does, but it can be decomposed with considerable energy liberation. It is dangerous to speculate upon the deeper principles of organic chemistry as applied to vital action but it seems that starch is a provisional storage so that the plant may use it at the proper time. Starch is insoluble in cold water and therefore is not readily subject to the attacks either of enzymes or microbes. A root or a tuber or a seed may thus hold for a long while the starch somewhat as a loaded shell or a cartridge may hold its explosive. If the carbohydrates of the plant were in the form of sugars or of

some of the nearly allied compounds soluble in water, they would rapidly become the prey of enzymes and microbes and would be decomposed. The form of starch therefore acts as a storage, under conditions of dryness, for an indefinite time.

The present volume is not taken up with the more abstruse questions in regard to starch. It deals with the material as a chemical in its varied uses. Nineteen topics are included, among which we may note as especially interesting the rôle of starch in bread making and starch in the fermentation industries. Its application to the development of adhesives is also an important feature. All the topics are in fact of high practical value. A historical note on the early development of starch chemistry concludes the descriptive part of the volume. The remainder of the book, more than half of it, is taken up with an elaborate detailed bibliography covering the literature from 1811 to 1925; facts about starch prior to the earlier date are treated in the historical chapter just noted. Patent literature is not included in the bibliography but a survey of it is in hand and the data will appear in a later volume. The work is illustrated and constitutes indeed a very excellent contribution to the industrial applications of a highly important and widely employed product of the vegetable kingdom.

HENRY LEFFMANN.

SIR ISAAC NEWTON, 1727–1927. A BICENTENARY EVALUATION OF HIS WORK. Prepared under the auspices of The History of Science Society in collaboration with several other scientific societies. Edited by F. E. Brasch. ix–351 pages, portrait, 8vo. Baltimore, The Williams and Wilkins Company, 1928. Price, $5.

It has fallen to many famous persons to have legends attached to their names which, though often frivolous, seem to be inerasable. George Washington has never got rid of the story of the cherry tree and Caesar has always had with him "Veni, vidi, vici." Similarly we are apt to think of the dropping of an apple when the name of Newton is mentioned. The story, like many other of these legends, appears much later than the event, occurring in an indirect relation. It does not seem likely that this was the starting point in Newton's thought on the great question of the general attraction of matter. Physicists, it may be remarked, have not been unanimously satisfied that the force that draws masses together is really an attraction. There have been speculations that at least the apparent attractions of the planets may be due to pressure, but at any rate the theory of Newton has dominated astrophysics for several centuries and its terminology is still used in the science.

The present work is a bi-centennial celebration of the birth of Newton, recording not merely his researches and writings but a critical estimation of the same. He was a puny infant whose life was more than once despaired of in its early period and it was fortunate that in those days, when so little was known about diseases and treatment, he weathered the storm of infancy and was preserved to an active life in the service of science. In addition to the legends which as noted above attach to the biographies of famous men, we often find that useful activity in one direction is overshadowed by other activities, thus preventing full appreciation of the man's work. George Washington, for instance, is famous as a general and as the organizer of the American union. Few know how active he was in engineering work, how much at heart he had the question of trans-

portations from the Mississippi Valley to the seaboard and how he labored to secure legislation to authorize transportation systems and capital to develop them. In no part of his life do we see any greater degree of forward-looking spirit and of appreciation of the importance of inter-state traffic to the solidarity of the American union than in his engineering work. Similarly it may not be generally known that Sir Isaac Newton had a great deal to do with another very important problem in the affairs of a nation, namely the stabilizing of the currency. During the confusion in England in the reign of the Stuarts with the breaking of conditions under the Cromwellian administration, the metal coinage of the realm had fallen into very unsatisfactory conditions. The "clipping" and "sweating" of it were extensively practiced with the result that the market value of the coins was very much out of accord with their stamped value. In such cases the poorer classes suffer almost exclusively. In the reign of William III "of blessed memory," Newton was made master of the English mint and under his supervision the silver coinage of the realm was reformed. The milling of the edges prevented the "clipping" and the sharpness and distinction of the stamping interfered with the practice of "sweating." As Macauley says, it was a new era when these silver coins "bright, heavy and strongly milled" came from the mint. In the collection of the Historical Society of Pennsylvania there is a receipt for bullion received at the Royal Mint signed by Newton.

Apart from his work on gravitation, we find another epoch-making discovery when he passed the light from an opening in the window of a dark room through a prism and saw the spectrum. Had the Greek philosophers made this experiment, they would not have been so puzzled to account for the hues of the rainbow. The aperture which Newton used was much too large to give him the real analysis of light. Long after Wollaston, by using a narrow opening, saw that the spectrum was not continuous and still later Fraunhofer mapped a few of the lines which now bear his name.

The many-sided character of Newton's mind is exemplified in his work in the higher mathematics and by contrast his interest in religious questions. It is rather uncommon now-a-days that the professional scientist of high rank takes interest in dogmatic religion or even in its ethical side. Such questions are usually put aside with consent as to the general propositions and the feeling that one's clergyman can look after the details.

The reading of this volume will be a most useful instruction to beginners in science for it will show them the basic objects of science study. It comes from the well-known Williams and Wilkins Press and sustains the reputation of the corporation and its motto.

HENRY LEFFMANN.

CRYSTALLOGRAPHIC TABLES FOR THE DETERMINATION OF MINERALS. By Victor Goldschmidt (Heidelberg) and Samuel G. Gordon (Philadelphia). 70 pages, 8vo. Special Publication No. 2, The Academy of Natural Sciences of Philadelphia, 1928. Price, $1.50.

Comprised within a small volume is an immense mass of information concerning minerals. Every distinct species known up to the date of the preparation of the book is included. The information is given in much detail. With the proper apparatus it is possible with this work to determine the nature of every

mineral. The tables include the specific gravity, composition, hardness, crystallographic data and brief descriptions of general properties. The printing is very clear, the numbers very distinct and the paper excellent. The work does not begin to show to the ordinary reader the vast amount of labor which has been expended upon it, but its service to the mineralogist will be very great. Both authors are now well-known in connection with mineralogy. The portion containing the statistical data is preceded by a brief introductory article.

HENRY LEFFMANN.

ELEMENTS OF OPTICS. By Joseph Valasek, Ph.D., Associate Professor of Physics, University of Minnesota. xiii–215 pages, 20 x 14 cm., cloth. New York, McGraw-Hill Book Company, Inc., 1928. Price, $2.

If modern physical research has given us new views on the constitution of matter, the manner in which the transfer of energy is effected and new conceptions of space and time, the influence of these new views has not yet changed the general plan of text-books of physics, and with the exception of refinements incident to modern progress and the supplementary treatment of the quantum theory, atomic physics and relativity, the subject is still presented as in the day of that fine old book, Ganot's Physics, so much in vogue during the latter part of the past century. As the author states the matter, ". . . the inclusion of these subjects must not be at the expense of the older and well-established fundamental principles. It is aimed in this text to preserve a proper balance between the old and the new in optics. . . ." The work accordingly covers the topics which are embraced in physical and geometrical optics with those relating to spectral phenomena, radiation and the recent concepts of matter, space and time reserved for the final chapters.

As is to be expected in a condensed course, the different methods which are available of studying various phenomena cannot be analyzed at length. Nevertheless they are very satisfactorily explained, and illustrated with excellent diagrams. Much ground is covered by the application of algebraic and trigonometric method and the use of graphic diagrams which now-a-days are understood by every serious reader. Laws which cannot be so derived are stated without derivation but with understandable explanation of their import. There is little choice in the quality of the presentation of the various topics, the work is indeed very well balanced, but especial mention may be made of the lucid and practical treatment of geometrical optics especially as applied to lenses. Many readers to whom bibliographical references in a book of this kind are of decided value will regret the omission of that feature. The work constitutes a sound and practical exposition of the principles of optics with the least possible mathematical attainment.

LUCIEN E. PICOLET.

NOTRE MISÈRE SCIENTIFIQUE, SES CAUSES, SES REMÈDES, L'APPEL DU ROI. Par Q. M. Quaeris et des collaborateurs. 56 pages, 25 x 16 cm., paper. Bruxelles, Etablissements d'Imprimerie Fr. Saey, Editeur, 1928.

The general appraisement of the condition of a public institution which falls short of meeting rightful expectations is always a logical first-step towards establishing normal functioning; it is the diagnosis which precedes remedial measures.

No less a personage than the King of the Belgians, at the celebration of the centenary of the celebrated Cockerill establishment at Seraing on the 1st of October, 1927 calls the attention of his countrymen to the necessity of according to Science an honored place in their land. The appeal has been promptly heeded. The Counsel of Administration of the Hoover Foundations for the development of the Universities of Louvain and Brussels held a meeting to consider the crises through which higher education and particularly advanced research is passing in Belgium.

The principal object in the issue of this work is to analyze in detail the causes of this lack of vigor in the progress of pure science. The author points out the small earning power of intellectuals due to the lack of balance of public appreciation of the value of cultural achievements against those of more direct appeal to the public mind. Other causes, notably bureaucracy and official prejudices, are noted and, in particular the trying experience of a well-known author of several important contributions to the literature of physical science in his efforts to obtain recognition in educational circles. Though primarily of local interest, the work is suggestive of the condition which may occur elsewhere and to a certain extent does occur elsewhere. It is a document that may well be commended to the thoughtful consideration of educational and administrative officials.

LUCIEN E. PICOLET.

WIRELESS PRINCIPLES AND PRACTICE. By L. S. Palmer, M.Sc., Ph.D., F.Inst.P., A.M.I.E.E., Head of the department of pure and applied physics, Victoria University of Manchester, Late radio engineer to the Admiralty. xi–504 pages, 21 x 14 cm., cloth. New York, Longmans, Green and Company, Ltd., 1928. Price, $7.

When wireless broadcasting first became available to all who cared to purchase or build a receiving set, there was little definite information in print to guide them. But the rapid and vigorous growth of the radio art has quickly resulted in the appearance of rational works in which the subject is treated in its multiplicity of detail as a definite engineering problem; engineering practice based upon low-frequency alternating current principles cannot be applied to problems concerning high frequency currents. The present treatise is especially well adapted to the needs of electrical engineers who wish to become conversant with wireless practice or for other serious readers who desire a rational and deductive exposition of the subject. A knowledge of the elements of electricity and magnetism and of alternating currents and with the mathematics employed in such treatises is essential to a wholly satisfactory perusal of this work, though the results formulated and liberal qualitative information are within the reach of others not so fully equipped.

A very complete survey of the subject is made. Beginning with a consideration of the general theory of wave motion and its application to the study of electromagnetic waves, a detailed study is made of the oscillatory circuit in terms of its essential components, inductance capacity and resistance. In proper sequence, the theory of the thermionic tube, methods of generating high frequency alternating currents by the tube oscillator and other methods are analyzed at length. Then comes a mathematical discussion of the electromagnetic theory and the propagation of wireless waves according to the methods of Maxwell. Detection and amplification are each given a comprehensive chapter. The two

final chapters on wireless cover in ample measure theoretical considerations and current practice of the devices and their auxiliaries which are included under these topics. Some of the features of value which may be noted are the well-executed and convincing diagrams, the ample bibliographies with each chapter and the excellent balance between the discussions of the theoretical and practical aspects of the subject. LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

The New Reformation from Physical to Spiritual Realities, by Michael Pupin. 273 pages, portraits, 12mo. New York, Charles Scribner's Sons, 1928, price $2.50.

The Elements of Industrial Engineering, by George Hugh Shepard. 541 pages, illustrations, plates, 8vo. Boston, Ginn & Company, 1928, price $4.80.

A Textbook of Organic Chemistry, by Joseph Scudder Chamberlain, PhD. Second edition revised. 901 pages, 12mo. Philadelphia, P. Blakiston's Son & Co., 1928, price $4.00.

Storage Batteries, Theory, Manufacture, Care and Application, by Morton Arendt. 285 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc. 1928, price $4.50.

A Quantitative Study of Chromatic Adaptation. A dissertation presented to the Faculty of Bryn Mawr College by Mary Ruth Almack. 119 pages, illustrations, 8vo. 1928.

The Effect of Intensity of Light, State of Adaptation of the Eye, and Size of Photometric Field on the Visibility Curve. A study of the Purkinje Phenomenon. A dissertation presented to the Faculty of Bryn Mawr College by Louise L. Sloan, 89 pages, illustrations, plates, 8vo. 1928.

The Geology of Petroleum and Natural Gas, by Ernest Raymond Lilley, Sc.D. 524 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928. price $6.00.

Chemical Encyclopædia, and Epitomized Digest of Chemistry and its Industrial Applications, by C. T. Kingzett, F.I.C. Fourth edition, 807 pages, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $10.00.

Michigan College of Mining and Technology. Bulletin 1927–1928, Announcement of Courses 1928–1929. 124 pages, illustrations, 8vo. Houghton, Mich., The College, 1928.

National Advisory Committee for Aeronautics. Technical Notes, No. 287, A dangerous seaplane landing condition, by Thomas Carroll. 3 pages, quarto No. 288, The reaction on a float bottom when making contact with water at high speeds, by H. C. Richardson. 4 pages, illustrations, quarto. Washington, Committee, 1928.

Report of the Commission appointed by Governor C. C. Young to investigate the causes leading to the failure of the St. Francis dam, near Saugus, California. 21 pages, 30 plates, 8vo. Sacramento, California State Printing Office, 1928.

CURRENT TOPICS

A Simple Method of Finding the Sound Absorbing Power of a Building Material. GUNNAR HEIMBURGER. (*Phys. Rev.*, Feb., 1928.) Prof. W. C. Sabine of Harvard developed a method of determining the absorption of building materials for sound. The material tested covered the walls of a room as in actual use and the human ear was the instrument for measuring the intensity of sound. Measurements thus obtained were slow in execution and involved considerable expense in the preparation of the room. In addition the ear requires long training before it becomes reliable for such work.

There is a second general method that requires a smaller amount of the material to be tested and uses, not the ear, but some really quantitative instrument, such as a telephone receiver, a hot wire microphone or a Rayleigh disc. The absorbing material closes the end of a tube that is adjusted to resonance with a steady source of sound, and measurements are made upon the system of standing waves set up within the tube, "usually by comparing the maximum energy value at an antinode with the minimum at a node." There is likely to be so great a disparity between the two quantities of energy to be measured that a small error in reading may cause a large final error. The author sets out to avoid this kind of error and develops a procedure that enables him to compare the absorbing powers of different substances, but not to measure them absolutely. The absorption coefficients are known for several materials so that comparison with one of these will lead indirectly to a knowledge of the coefficient. "The main idea of the method is to compare the values of the *maximum* sound intensity in the standing wave in the tube in the cases when the end of the tube is closed first with a hard material and then with the material under test. These values are always large enough to be accurately measurable, and with care in the experimental arrangements they may be made constant and reproducible."

In the paper a formula is derived for the ratio of the energy at an antinode of the tube when its end is closed by absorbent material to the value when its end does not absorb. The wave from the source of sound passes along the tube, is reflected from the closed end, traverses the tube in the opposite direction and is reflected a second time from the open end and continues up and down the tube with reflections at both ends. The formula contains the

absorption coefficient, a, at the closed end and also the coefficient, b, at the open end. The former, a, is the goal of the measurement. Fortunately b can be obtained since it is a constant for the same tube when carrying waves of one pitch. The ratio also can be measured so that the coefficient, a, can at last be calculated.

Two organ pipes, stated to be free from appreciable overtones, were used. The lower one with a frequency of 295 vibrations per sec. furnished the waves from which the data below were derived. The resonance tube 70 cm. long had a square cross-section 7.5 by 7.5 cm. For intensity measurements a Rayleigh disc consisting of a mica disc 1 cm. in diameter suspended by a quartz thread 2.5 cm. was inserted into the tube. This instrument showed that the energy at the four antinodes existing in the tube was not the same for all but decreased by 1½ per cent. in passing from the antinode nearest to the open end to the one farthest in the tube.

Seven materials, all with coefficients already known from experiments made upon them by Sabine's method, were studied. They were Celotex, Akoustikos, felt, Akoustolith tile and Rumford tile. By two different methods the coefficient of absorption at the open end was found to be .24. In five of the seven cases there was close agreement between the coefficient found by Sabine's method and that derived by the much simpler procedure described in this paper. The largest value of the absorption coefficient, 43 per cent., was, in the case of Akoustikos, ½ inch thick, and the smallest, .15 for Akoustolith tile. The ratios of the energies at antinodes varied from .109 to .417 for the two substances just named.

A method of direct practical value appears to have been developed by the author. G. F. S.

The Preparation of Large Single Crystals. H. S. RAMSPERGER and E. H. MELVIN. (*Jour. Optical Soc. Am.*, Dec., 1927.) Lyman found that a pure specimen of natural fluorite transmitted radiation of wave-length as short as 1230 A., but now suitable crystals of this substance are not available for the construction of vacuum spectrographs transmitting thus far into the ultra-violet. There is need of crystals larger in size and optically clearer. Even as little as .01 per cent. of certain impurities will notably reduce the transparency of the crystal in the region of very short wavelengths. The purpose of the technique later described is to obtain large crystals of very pure compounds with a view to their use in optical researches in the ultra-violet.

There are two general methods of getting large crystals from molten masses. In one the liquid is cooled very slowly

by means of a device applied to its upper part. In the other the liquid cools from below upward. "Stober had shown that in the case of bismuth metal, sodium nitrate, and sodium chloride the entire dish could be crystallized as a single clear crystal. We have used this method, making some improvements in the apparatus." The crystal must start to form at some point and this point must be the lowest point of the containing dish. There must be a uniform temperature gradient from top to bottom so as to avoid the development of a second crystal and the flow of convection currents. Cooling must be so slow as to prevent the occurrence of strains. The authors found no great difficulty in meeting these conditions except in the avoidance of strain. All the molten material turned into one large crystal, but sometimes near the completion of cooling this broke up into smaller crystals that in polarized light showed evidence of strain. This was traced to the adhesion of the molten liquid to the platinum containing crucible. The metal has a thermal expansion coefficient different from the crystal. Due to this difference, as cooling proceeds, a state of strain is produced. A vain search was made for a material from which a dish could be made not wetted by the contained molten salts. Though platinum is wetted by all the salts used no better material was found. It was, however, used in foil .0025 cm. thick and free from alloy. The pure platinum was almost as malleable and soft as gold, and its thinness reduced the strains so that the resulting crystal no longer automatically broke.

The crucible in which the melting and subsequent crystallization took place was cylindrical with vertical sides closed below by a conical portion ending in a point where the crystal began its development. The crucible was surrounded by a block of insulating material. Both above and below it were electrical heating units. The compound in solid form was put into the crucible. The upper unit was turned on and the compound was raised almost to its melting point. Then the lower unit was brought into play and the substance was melted. By reduction of the lower current a gradual cooling was attained and the crystal began to form. Lowering of the upper current finally by slow stages brought the crystal to room temperature. "The crystallizing was usually done in 24 hours, and the cooling to room temperature in 100 to 120 hours." The variation of voltage on the electric line circuits made necessary the use of a thermostat. The

apparatus was applicable up to 1,500° C. Crystals of lithium fluoride, sodium chloride, sodium nitrate and mercuric bromide have been produced. The largest crystal obtained was of lithium fluoride. It filled the entire container, being $1\frac{3}{4}$ inches in diameter and $1\frac{1}{2}$ inches from top to bottom.

G. F. S.

The Motion of Water when Traversed by Rapidly Moving Spheres. CARL RAMSAUER. (*Ann. der Phys.*, Vol. 84, No. 22.) A steel sphere, used for ball bearings, was shot from a gun with smooth bore into a body of water. The experimental problem undertaken by the author was to photograph the water as the projectile passed through it. The ball was 11.003 mm. in diameter and had an initial velocity of 650 m./sec.

Much attention was given to securing a suitable container for the water. Glass was too fragile and too expensive. Celluloid proved itself satisfactory. A sheet of this material about 50 cm. wide and 60 cm. long was bent so as to form two vertical sides joined by a curved portion below. Two ends of celluloid as thin as paper were fastened to this bent sheet thus forming a trough open at the top. The end pieces had to be replaced after every shot, though the sides could be used several times. Sparks from Leyden jars provided the illumination for photographing the water. A timing device was operated by the water scattered by the impact of the ball. The ball went horizontally through the water, its path being about 7 cm. below the surface of the water so that it was surrounded on all all sides by some 7 to 8 cm. of the liquid. A series of photographs is reproduced showing the state of the water at different stages of the process. They are by necessity pictures of what occurred during different shots and not successive pictures during the same shot. A typical view, when the ball is a little more than half through the water, shows no disturbance in front of it. Behind it and extending from its momentary position back to the wall of the trough through which it entered there is a vacant space from which the water has been ejected. Near to the ball this space has the form of a paraboloid, farther back it is conical, while close to the end of the trough it becomes cylindrical. Its diameter in a rough sense increases from the projectile backward, the maximum diameter being dependent upon the distance in the water to which the ball has penetrated.

An inspection of the free surface of the water shows that there is far less distortion of it than would be expected. In some of the photographs the profile of the surface remains almost a straight line and careful examination is required to convince the observer that the water has moved upward at all. In cases for which the path of the ball lies nearer to the surface it is plainly seen that the water surface has been driven upwards. When the path lay 2.5 cm. below the surface the conical space formed behind the ball is clean but almost half of it lies above the level of the undisturbed water. Through the hole in the celluloid by which the ball enters the water a considerable quantity of the liquid is scattered backward. A smaller beam of the liquid emerges through the aperture made in the front wall of the trough. Even after the ball has left the containing vessel the empty space behind it continues its development within the vessel.

G. F. S.

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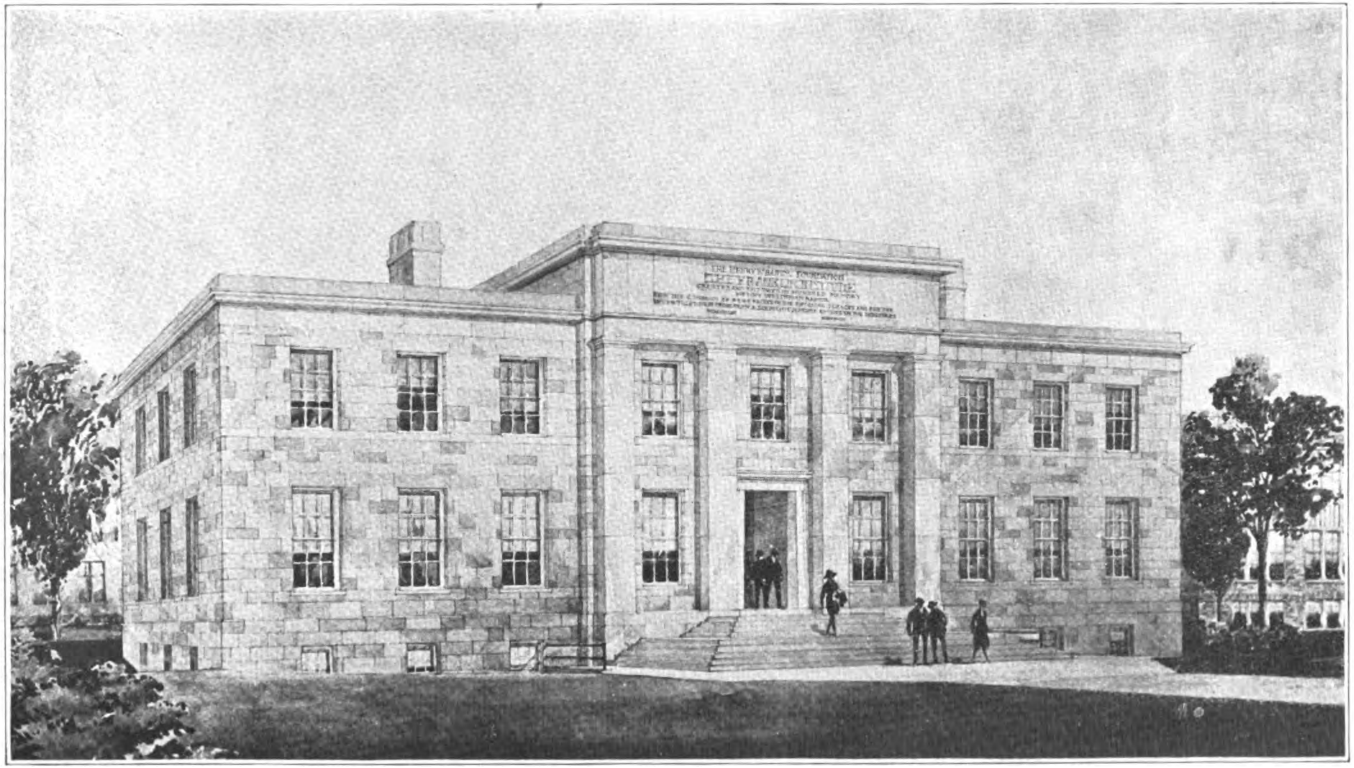

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PHYSICO-CHEMICAL CONSIDERATIONS IN ASTROPHYSICS.*

BY

PROFESSOR DOCTOR WALTHER NERNST,

Professor of Physical Chemistry, University of Berlin.

AMONG the greatest advances which astrophysics has made in recent years, undoubtedly belong the apparently extremely reliable determination of the age of the earth, which has been arrived at on the basis of measurements by numerous investigators using the methods and theories of radio-activity. It is now regarded practically everywhere as certain that the production of the solid crust of the earth took place about sixteen hundred million years ago.

We make the following assumptions:

1. The earth was split off from the sun as a ball of fire of high temperature.

2. The Universe is in a stationary condition, that is, the present fixed stars cool continually and new ones are being formed.

So far as the first assumption is concerned, I cannot conceive that it can really be brought into question; all other assumptions, of whatever character, appear so extremely artificial that they, at least for the present, can scarcely be dis-

* Read by Dr. Irving Langmuir.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

cussed seriously. The second assumption appears at the outset to be wholly arbitrary and so it is to a certain degree but nevertheless it appears that hitherto every prominent investigator has accepted this assumption simply as an intellectual necessity. Moreover, I believe also that many proofs, if not of the correctness, yet at least of the usefulness of this assumption, have appeared.

By the aid of these two hypotheses we come to the following far reaching conclusions: the cooling of the highly heated yet fairly small earth must obviously have taken place quite rapidly so that the total age of the earth, i.e., the time which has elapsed since the separation of the earth from the sun, is likewise to be put at about sixteen hundred million years. The conjecture is a ready one, and previously has been generally made, that the formation of the planets came early in the life-history of the sun. Also on the basis of star data, one can regard this time as relatively short so that we finally arrive at the result that the age of the sun is to be put at scarcely more than two thousand million years. The demonstration just indicated is moreover nothing other than a direct application of our second hypothesis. The number of stars which are in the adolescent state, i.e., the "red giants," is known to be not very great; it therefore follows that the duration of this "state" can be only short.

We come now to the fundamental question, whence do the sun and the other fixed stars obtain the incredible amounts of energy which, during periods of time that are to be measured in thousands of millions of years, are sent out into the Universe in the form of radiation? Quite some time ago I showed that, if we are not willing to make highly fantastic hypotheses such as have been tentatively suggested by many astrophysicists, this source of energy must be sought for only in radio-active processes because these are the only ones which offer, even approximately, the amazing amounts of energy which come into play. But it may be asked whether even these are actually great enough and whether we can say anything concerning the kind of radio-active element involved.

Of the radio-active elements known to us, uranium comes first into consideration, but here a simple calculation shows that, even if the interior of the sun consisted predominantly

of uranium, which in itself would not be impossible, only about the half of the sun's energy could be supplied by this element through radio-active decomposition, especially through several thousands of millions of years. We recognize therefore that if, instead of uranium, we imagine an element which with equal radio-active development of heat, decomposes many times more rapidly than uranium, we should be able to explain satisfactorily the behavior of the sun with reference to its radiation of heat, at least in its present condition.

But now the following is to be observed: the sun is a fixed star which already has cooled off markedly: from star data, we conclude that the sun formerly must have radiated for a time about sixty times as much energy as at present. We recognize therefore that we must assume the coöperation not only of radio-active elements which decompose more rapidly than uranium but which at the same time must give up in the decomposition considerably more energy than uranium. I had therefore, at that time, surmized that the sources of the energy of the fixed stars must be looked for in radio-active elements which are of higher atomic weight than uranium.

The assumption that there are radio-active elements beside uranium, thorium, etc., which decompose more rapidly and in so doing also give off even greater amounts of energy, is not necessarily inherently fantastic; but one can indeed remain wholly skeptical with reference to such an *ad hoc* hypothesis. But when I set up this hypothesis, I could refer to a puzzling, extremely penetrating radiation, the Hess-Kolhoerster radiation, which is consonant with the conjecture that in the Universe such radio-active elements as we need must be present in incredible amounts.

Not much was known at that time of these radiations. I have therefore been eager to see that this remarkable radiation should be further investigated for, according to the considerations set forth for an understanding of the cosmos, this must be of the greatest significance.

The admirable works of Kolhoerster have proved definitely that we are concerned with a very much harder radiation, that is, one of shorter wave-length, than we meet with in the gamma radiations from the radio-active elements known to

us, whence it results with greater probability that there are in fact radio-active elements which are able to yield much more energy than those known to us. One may therefore well say that in recent years my hypothesis concerning the source of the energy of the sun and the fixed stars has received confirmation. It is time to seek by all suitable means this most important element in the earth also.

But there is another way than that mentioned above, that is, the isolation of one or more of these hypothetical elements, to make clear the nature of this wonderful cosmic radiation, and this other way should be of especial interest to The Franklin Institute, and I will therefore explain it briefly. We can designate the cosmic radiation as a very hard Roentgen radiation, and from the slight absorption of this radiation by matter we can make at least an approximate estimate of its hardness. The latter will be so much the greater, the higher is the potential difference by which the corresponding negative electrons need to be accelerated in a vacuum tube. We may estimate that from five to twenty million volts would be necessary for the artificial production of this cosmic radiation. In our laboratories we are as yet far short of producing such high potentials; but some years ago three young investigators, Messrs. A. Brasch, F. Lange and C. Urban, in my Berlin laboratory, hit upon the idea of repeating with modern apparatus the most famous of all meteorological experiments, namely, Franklin's.

In the neighborhood of Monte Generoso in Switzerland, i.e., in a region where thunder storms are frequent and violent, they have already been able, in the past years, to draw continuous sparks of about four meters length (corresponding to about two million volts) from a gigantic antenna, and it cannot well be doubted that yet much higher potentials can be made available for measurement and use. The above named young physicists are now occupied in repeating on a still greater scale Franklin's experiment; the problem in further investigations will then be to bring about, in addition to the breaking up of the atom, the production especially of cosmic radiation on our planet. Recalling the famous Latin verse which concerned Franklin, "Eripuit cœlo fulmen, sceptrumque tyrannis" one can unfortunately not forget that it is

scarcely less hazardous to tear the lightning from the heavens than the sceptre from tyrants; we shall therefore hope that the precautions contemplated by the young physicists will prove themselves efficacious with even the strongest lightning flash.

Evidently, the question as to the age of the sun and of the fixed stars is a fundamental problem for astrophysics. I have endeavored to find another way, and I indicated some time ago a method, which would permit us to reckon at least an upper limit with confidence. We know from Einstein that a body loses mass when it gives off energy; if the sun had shone for somewhat more than ten trillion years with the same brilliancy as today, its mass would have vanished into the universe in the form of a radiation. This period of time is therefore an upper limit to the age of the sun and we may immediately add that, since in the first place the sun in its earlier life radiated energy much more rapidly than it does today, and since in the second place, for many reasons, the amount of the mass which has vanished can scarcely form a very considerable portion of the total mass, the above indicated upper limit is much too high. The calculation just mentioned makes it therefore in the highest degree probable, indeed almost certain, that the age of the sun cannot amount to a hundred thousand million years. Certainly the superior limit thus determined is considerably greater than the value fixed by me above as the most probable, namely, two thousand million years. But on the other hand, we should be pleased to have the proof that the age of the sun must lie between two definitely given limits.

Perhaps the following consideration, which rests upon wholly different principles, is not altogether without interest. The "red giants" which are according to our conception stars whose age amounts apparently to only a quite small fraction of a thousand million years, have a very slight proper motion. We will assume that the sun, which it is known possesses at this time a velocity of about twenty kilometers per second, originated somewhere at a great distance from its present position and by a gradual increase of its velocity it has wandered into its present location. We might then in this manner ascribe to the sun, as a first approximation, the mean

velocity of ten kilometers per second, and we could then easily calculate that it, in the two thousand million years which we concede to it, has traversed a path of about one hundred thousand light years. It is not improbable that the sun at such a distance from its present-day position was formed by the agglomeration of more or less radio-active material, and even if this assumption cannot be regarded as a confirmation of the age of the sun figured out by me, yet one can at least say that the above result does not appear nonsensical.

In accordance with this conception, the sun, after an additional two thousand million years during which it will have become a red star of small luminosity, will have joined the numberless cold stars of our Milky Way which because of their distance and low luminosity are today invisible to us. But this result involves a difficulty which appears at once in the conception here portrayed and which I have felt forcibly; we must according to the principle of the stationary condition, meet with the distant cold stars incredibly more frequently than the fixed stars in the sole condition in which they are visible to us as hot glowing bodies, since the ordinary chemical elements are certainly extremely weakly radio-active and therefore decompose only extraordinarily slowly. But if, driven by forces which are wholly unknown to us at the time, the sun and the other stars pass over such orbits as we have calculated, the cool stars are so far removed from us that in spite of their extraordinarily great abundance we have no means of any sort of distinguishing them.

In conclusion, I may point out a few contradictions which exist between the principle of the stationary condition and the generally recognized requirements of physics and of physical chemistry.

In the first place, all natural processes take place finally in such fashion that existing difference of temperature always comes to a state of equality; and in the second place, the radio-active processes always occur as a disintegration, i.e., elements of high atomic weight decompose into those of lower.

The two phenomena become compatible with the principle of the stationary condition only if in some possible way a deviation, and one of even x large degree, occurs in the direc-

tion in which the above named natural processes are carried out. In other words, the investigator of Nature stands before the choice, either to relinquish the principle of the stationary condition, which above was characterized as an intellectual necessity, or to assume a possible continuous failure of the two above mentioned natural laws. In view of our considerations, we are naturally forced to follow the latter course.

In recent times the notion has been frequently expressed that the energy of radiation from the stars is produced by the combination of four hydrogen atoms to form one helium atom, in which indeed, according to Einstein's formula, a mighty evolution of heat must occur on account of the disappearance of mass which is involved. I cannot admit that this conception would be in any manner compatible with our known experience. Such processes as those indicated above, could take place only with incredibly high temperatures, such as we must regard, on the basis of our former knowledge of the cosmos, as never existing. Even in the interior of the hottest stars, no higher temperatures than about thirty millions of degrees could occur as Eddington has convincingly proven for otherwise the light pressure would cause the star to explode. But reactions between atomic nuclei bring into use wholly incredibly high temperatures as can be demonstrated with the highest probability, in different ways. The salvation of the principle of the constant state is not won with the assumption of the formation of the helium atom out of hydrogen atoms.

I may therefore hold fast to the hypothesis uttered by me that, just as the principle of the stationary condition of the cosmos demands that the radiation of the stars be absorbed by the luminiferous æther, so also finally the same thing happens with mass, and that, conversely, strongly active elements are continually being formed from the æther, though naturally not in amounts demonstrable to us, the radio-active disintegration of which maintains correspondingly the high differences of temperature which are observed in the Universe and which at the end form the driving force of all the processes of nature in the direction demanded by the second law of thermo-dynamics. This simple hypothesis would therefore restore to us the stationary condition of the cosmos.

Naturally, this hypothesis is not demonstrable in any manner directly; in any event, it may be indicated that "the wave theory of matter," this newest and most promising offspring of modern physics, lends to the processes demanded by my hypothesis a certain probability. But obviously one must be quite clear that such an hypothesis lays claim to nothing more than the expression of a logical possibility: the knowledge of the true inwardness of things lies yet in the remote distance.

Is there any purpose in forming at this time such a naturally uncertain hypothesis? I may answer this question by saying that it is ultimately a matter of taste. To me personally, an hypothesis which is as logical as may be, brings much even if it cannot lay any claim to great reliability, and I venture to believe that everyone who delves further into the described hypothesis will think likewise. Moreover, science is indeed rich in hypotheses which in passing exercise a considerable stimulating force even if later they have to be greatly modified. As examples, I might name the corpuscular emission theory of light in the realm of physics and the phlogiston theory of the chemist. Astrophysics, which on the one hand may claim for itself that it deals with the most interesting questions of physical research is, on the other hand, more than any other science, dependent upon daring hypotheses.

SOME EXPERIMENTAL EVIDENCE SUPPORTING THE KINETIC THEORY OF GRAVITATION.

BY

CHARLES F. BRUSH, M.E., M.S., PH.D., D.Sc., Eng.D., LL.D.,

Member of the Institute.

SOME time ago I was advised by the Secretary that The Franklin Institute had honored me with the award of the Franklin Medal. This I esteem a very great distinction, of which I beg to express my deep appreciation.

The Medal was awarded for the pioneer development of the electric arc light, and the invention of the practical storage battery. The early development of the arc light was celebrated by the Institute last month, and I shall not treat of it further. But of the early history of the storage battery very little is known to the public, so I hope I may be pardoned for giving a brief statement of it.

The Planté secondary battery had long been known. This consisted of two lead plates immersed in dilute sulphuric acid. When an electric current was passed through the combination a very thin layer of peroxide of lead was formed on the surface of one plate while hydrogen gas was evolved on the other plate. After a time the charging current was reversed, resulting in reduction of the thin coating of lead peroxide to spongy metallic lead, and peroxidation of the surface of the other plate. Many more reversals of charging current were made at increasing intervals for several weeks or months, whereby a considerable coating of peroxide of lead was formed on one plate, and an equivalent coating of spongy metallic lead on the other plate. The capacity of such a storage battery cell was small and its cost prohibitive from a commercial standpoint.

It occurred to me that larger capacity and very much quicker preparation might be secured by initially coating the plates with a paste of lead oxide and sulphuric acid, which was found to adhere fairly well. The scheme proved quite

successful. This was in 1878. Later, the plates were made cellular, to receive a larger amount of the paste and hold it more firmly. A vast amount of experimental work followed. Patents were applied for in 1881, and after several years of interference litigation in the Patent Office, the famous patent No. 337,299 was issued March 2, 1886. It claimed "mechanically-applied active material or material adapted to become active." This exceedingly broad claim was afterward fully sustained by the Federal Courts, and controlled all practicable forms of storage batteries until expiration of the patent in 1903. Unfortunately for me, no great field of usefulness for the storage battery developed until after the fundamental patent had expired.

In the early nineties I retired completely from the electrical field of effort for the express purpose of gaining more available time for research in pure science. I have always keenly enjoyed hunting for new phenomena in physics and chemistry; and occasionally I have experienced the thrill of finding one, and the joy of investigating it.

But, fortunately perhaps, my research work has always been largely mixed with business affairs. In 1893 I helped organize and finance a company for the manufacture of portland cement, and have been one of its officers ever since. The company has been highly successful and profitable. About 1905 I organized "The Lindé Air Products Company" for the commercial manufacture of oxygen from the air. I was its president for several years until its business was firmly established. Then, finding it was taking far too much of my time, I negotiated a satisfactory arrangement with the Union Carbide Company whereby the latter took over the business management of the Lindé Company while I retained my large interests. The Lindé Company has now grown to very large proportions, and I am rather proud of it as one of my children.

In 1910 I had the honor to formulate and make public "A Kinetic Theory of Gravitation."[1] This has become known as the ether-wave, or energy-shadow theory. The only new postulate required by the theory is that some, or perhaps all, of the vast instrinsic energy of the ether exists in wave form of some sort capable of motive action on par-

[1] *Science*, March 10, 1911; *Nature*, March 23, 1911.

ticles, atoms or molecules of matter, and propagated in every conceivable direction so that the wave energy is isotropic. The waves are of such frequency, or otherwise of such character, that they pass through all bodies without obstruction other than that concerned in gravitation and a slight heating effect in some substances, and perhaps other slight effects. Distribution of the ether's energy is assumed to be uniform throughout the universe except as modified by the presence of matter.

The Kinetic Theory clearly indicates that the energy acquired by falling bodies is derived from the ether; and in subsequent papers I have submitted most convincing argument that this is true.

The Secretary has honored me with an invitation to make an address on the present occasion, on any subject I may select, preferably about some phase of my own research work; and I have chosen as my text "Some Experimental Evidence Supporting the Kinetic Theory of Gravitation."

Study of the nature of gravitation is beset with unusual difficulties, because gravitation is ever with us and about us; it is the one universal phenomenon, and we cannot escape from its influence—cannot obtain any outside point of view.

From the beginning of my experimental work on the problem of gravitation, many years ago, I have largely directed my efforts toward finding some evidence of the postulated ether waves other than gravitation itself; and it has seemed quite possible that such evidence might be furnished by a continual slight generation of heat within some substances specially adapted to exhibit it. The following argument will make this conception clear:

Heat is often defined as an agitation of atoms and molecules of matter, and measured by the total kinetic energy of such agitation. The agitation consists partly in internal vibrations of the elastic atoms and molecules and spinning about their various axes, and partly in a very rapid translatory motion among themselves. Thus they are supposed to dart about in every conceivable direction, constantly colliding with each other and rebounding or glancing in new directions. The kinetic energy of this translatory motion constitutes *sensible* heat (not total heat) and is the measure of *temperature*.

Anything (such as absorbed radiation) which stimulates the internal vibration of atoms or molecules likewise increases their translatory velocities by the increased violence of rebound after collision, and thus increases their temperature; and *vice versa*.

All the above is known to be true of gases and vapors (kinetic theory of gases), and is generally believed to be true of liquids and solids.

The "*mean* free path" and the "*mean* velocity" between collisions of the molecules of many gases under stated conditions have been computed. But it has also been shown mathematically that the higher and lower velocities, and the longer and shorter paths differ greatly from the means, and may in each respect vary twenty or more times in amount. Doubtless this is true also of liquids and solids.

From the fortuitously wide variation in velocities and free paths of the billions of vibrating atoms or molecules in their heterogeneous movement, it follows that collision frequencies must also vary greatly, from instant to instant, everywhere in a body of matter.

Probably the postulated gravitation waves are not confined to one frequency, but have a wide range of frequencies as do the well-known X-rays.

With the foregoing in mind it is easily conceivable that some kinds of matter may have atoms or simple molecules or complex molecules of occasional vibration frequency corresponding with some gravitation wave frequency, whereby fortuitous resonance can, for brief instants, be established at various points. This would result in a slight increase of vibrational activity and a cumulative rise of general temperature, perhaps sufficient to be detected.

A body of such matter, with some thermal insulation, would become and remain permanently warmer than a neighboring body similarly circumstanced, but not endowed, or less endowed with the permissive heat-generating quality.

The foregoing hypothesis had been my guide in a very lengthy search for some material exhibiting continual generation of heat in observable amount.

Two quite different calorimeters, very carefully designed and constructed, have been in frequent use for many years,

testing many metals and alloys, and also rocks and minerals for some slight and continuous generation of heat. Incidentally this research long ago led to the discovery of "spontaneous generation of heat in recently hardened steel," a new phenomenon, now well recognized in the metallurgy of steel.

The calorimeter work with rocks and minerals developed the fact that some of these substances do generate heat in easily observable amount, not due to radioactivity. The Bureau of Standards, with a calorimeter of its own design, is working with some of these minerals for the purpose of checking my findings.

It is notable that the materials which appear to be endowed with persistent heat generating activity are complex silicates; and it seemed highly probable that some silicates may be very much more active than others. This now appears to be true.

Guided by this thought I prepared and tested many artificial silicates. A silicate of the protoxides of nickel and cobalt showed very large activity, larger than either silicate alone; and this activity, after nearly two years aging of the silicate, appears to be permanent.

In the absence of other explanation, it has been thought that persistent generation of heat in some rocks and minerals, not due to radioactivity, is due to isotropic ether waves of great penetration; and in the light of more recent experiments, it is now thought that these ether waves are in the same class, perhaps having a wide range of frequency, with those postulated as the cause of gravitation.

Conversion into heat of some of the energy of the gravitation ether waves, however little, might be expected to impair, to some extent, the falling velocity of a heat generating substance; *and all such substances thus far tested have clearly shown impairment.*

I have yet found no exception to this remarkable phenomenon, though I have already tested many natural and artificial minerals. Substances which have shown no generation of heat in the calorimeters show no impairment of their falling velocity when compared with lead. Substances exhibiting small, moderate or large generation of heat have shown comparatively small, moderate or large impairment of

their gravitational acceleration. I aim to continue this research until the quantitative relationship of the two phenomena is ascertained. This may open a fertile field for mathematical exploration.

In making the above indicated comparisons of falling velocities I have largely used the method and apparatus described and illustrated in my 1923 paper on "Some New Experiments in Gravitation." [2] (See also 1924 paper of same title.) [3]

Two aluminum containers are used, alike in size, shape, weight and smoothness of surface, and dropped *simultaneously*, side by side through exactly the same distance (about 122 cm.).

Each container, at the end of its journey, breaks an electric circuit. But the breaks of both containers are in series in the same circuit, so that the break which occurs first produces a bright spark, while the belated break gives no spark because its circuit is already open.

When the containers are equally loaded with the same metal, there is no visible spark at either break or a very feeble spark at one or the other indifferently. But when they are equally loaded with certain different metals, one container persistently produces a bright spark, though the containers are always reversed in position for each trial. From this it seems clear that the container giving the spark falls a little faster than the other. This sparking condition is clearly manifested when the faster container reaches the end of its free path as little as .0125 mm. (.0005 inch) in advance of its neighbor. This indicates a time difference about 1/400,000 second.

To facilitate estimation of larger falling velocity differences I am perfecting a photographic method of observation. After falling about 110 cm. the small lower ends of the containers are photographed in silhouette against a white background having many horizontal black lines, and illuminated by a bright electric spark timed by allowing the conical shoulder of one container to contact with a fine, very flexible, steel wire. Duration of the spark is so brief, probably much

[2] *Proc. Am. Phil. Soc.*, Vol. LXII, No. 3, 1923.
[3] *Proc. Am. Phil. Soc.*, Vol. LXIII, No. 1, 1924.

less than a millionth of a second, that the container tips are practically stationary while being photographed.

After each exposure the right and left position of the containers is reversed and the photographic plate is so screened that only a horizontal strip is used at once. Thus eight exposures are made on one plate by suitably moving the plate-holder after each exposure.

In a recent experiment a marked container was filled with silicate of nickel and cobalt tightly packed; while the other container was loaded with an equal weight of lead sawdust (and cork) held firmly in cylindrical shape by a tightly fitting cork.

Each of the eight photographs on the same plate clearly showed the silicate container slower than its companion. Several more similar plates made with the same loaded containers all showed the same effect.

Of course I tried exchange of loads in the containers, but without observably affecting the result; the container holding the silicate was always slow.

The observed retardation of the silicate container must be due to impaired gravitational acceleration of the silicate as compared with the lead sawdust in the other container; and as the silicate constitutes only 30.8 per cent. of the total mass undergoing acceleration, we must multiply the observed retardation by 3.25 to find the full impairment of the silicate alone.

Micrometer measurements of the photographs will be made to find the quantitative value of retardation of the silicate.

Other materials tested by the photographic method have shown similar retardation in lesser degree.

Correlation of continual generation of heat in some substances and impairment of their gravitational acceleration, is regarded as very strong evidence in support of the kinetic theory of gravitation; and we seem now well started on the way of finding out something definite about the nature of gravitation, which is by far the greatest of all outstanding physical problems.

Electro-capillary Microphone. M. LATOUR. (*Comptes Rendus*, Jan. 23, 1928.) A capillary tube which is considerably wider above contains an electrolyte such as water to which an acid or a salt has been added. Its narrow part is sunk into a vessel of mercury. A layer of oil covers the electrolyte to prevent evaporation. Two wires run into the mercury and the electrolyte to secure good electrical contact. If a telephone receiver be connected between these two wires it reproduces sounds made some distance from the apparatus. The insertion of a capacity in the receiver circuit does not stop the emission of sound. This shows that there is in play an alternating electromotive force and not merely a direct current varied by changes of resistance. When an alternating E.M.F. of musical frequency is applied to the two wires the arrangement acts as a telephone receiver.

G. F. S.

The Speed of Waves in Radiotelegraphy. A. LAMBERT. (*Comptes Rendus*, March 12, 1928.) The speed of radio waves seems to be considerably below that of light. By the use of signals sent out from Honolulu and Saigon and observed at San Diego and Zikawei the greatest speed was obtained, viz.—293000 km./sec., while in another set it came out as small as 210000 km./sec. The mean value was 247000 km./sec.

G. F. S.

KERR EFFECT IN WATER DUE TO HIGH FREQUENCY RADIO WAVES.

BY

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BARTOL RESEARCH FOUNDATION
Communication No. 26.

VARIOUS investigators who have measured the index of refraction of water for short radio waves, i.e., for wave-lengths between 300 and 3 cms. have found evidence of the existence of absorption lines in this region. Since it is phenomena of this type which render the measurements of the dielectric constant of aqueous salt solutions by high frequency bridge methods so uncertain, an investigation of these bands ought to be of considerable service in elucidating these difficulties. The existence of bands in this region would also help to explain the discrepancy existing between the value of the dielectric constant as calculated from the index of refraction and the intensity of infra-red band spectra and that given by direct experiment.

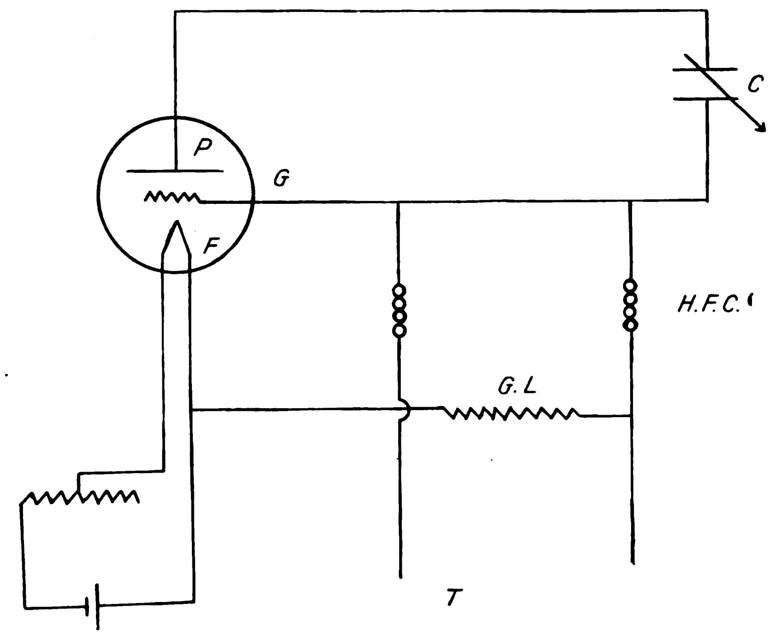
A diagrammatic sketch of the oscillator used in these experiments to produce the short electromagnetic waves is shown in figure 1.

The variable condenser *C*, shown in the above figure, which was used to adjust the frequency of the oscillations, had a capacity which could be varied from 400 cms. to 60 cms. In this work care should be taken that the oscillatory circuit be well insulated from ground, a satisfactory method being to mount the apparatus on a large glass plate, and also that all magnetic material such as transformers, etc., be at least 1 m. away from the circuit to avoid the induction effects of the high frequency waves.

The most accurate method which suggested itself for showing the existence of the electric spectrum of water, was one involving the measurement of the Kerr effect in water produced by the electromagnetic field of the oscillator. The

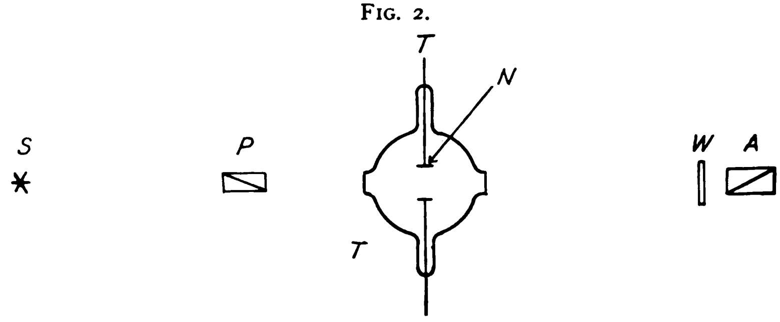
electric double refraction due to this field was measured for sodium light by the apparatus shown in Fig. 2.

FIG. 1.



P, *F* and *G*, the plate, filament and grid of the oscillator.
G.L., grid leak of 40,000 Ω.
H.F.C., high frequency choke.
T, transformer supplying 1,500 volts on the secondary.

FIG. 2.



This consists of a source *S*, a sodium gas burner, the Kerr tube *T* which was placed in parallel with the condenser *C* of Fig. 1 and contained two nickel plates placed parallel to the

axis of the tube and 1.6 cm. apart, and supported by tungsten leads sealed through the glass wall. The retardation was observed by means of the polarimeter, consisting of the analyzer A, the polarizing nickel P, and the quarter wave plate W. In the operation of this apparatus, light from the source S passed through the polarizing nickel P into the Kerr cell T along the axis of the tube between the plate electrodes and then through the analyzing system W and A.

Before we discuss the experimental results, however, we shall investigate the nature of the electric field in the cell T on the supposition that the medium in the cell, in this case water, has an absorption band within the range of the high frequency electric alternations applied to the cell plates.

If we let ν_s = the frequency corresponding to the center of the absorption band,

ν = the frequency of the electromagnetic waves produced by the oscillator,

E = the electric field intensity in the absorbing medium due to the high frequency alternating current of frequency ν,

and D = the electric induction,

then, according to Lorentz' theory of dispersion

$$D = \left[1 + \frac{\dfrac{\alpha}{\nu_s^2 - \nu^2}}{1 - \dfrac{\beta}{(\nu_s^2 - \nu^2)}} \right] \cdot E = \left[1 + \frac{\alpha}{\nu_s^2 - \nu^2 - \beta} \right] \cdot E,$$

where α and β are constants depending on the structure of the dispersive medium.

If we were to plot the values of D^2 against frequency ν for a constant value of E, we should find according to the above equation that as the frequency increased, the values of D^2 would increase from E^2 until it became infinite when

$$\nu_s^2 - \nu^2 = \beta,$$

then drop to zero when

$$\nu_s^2 - \nu^2 - \beta = -\alpha,$$

then increase again to infinity when

$$\nu_s^2 - \nu^2 = \beta,$$

and then decrease towards E^2 as ν was further increased.

If, however, we had taken into consideration the absorption of the radiation due to the resistance of the damping term, then we would have had a similar graph except that the value of D^2 would have approached a large maximum value instead of becoming infinite in the neighborhood of the absorption line.

From our knowledge of the electric field inside the medium, we are now in a position to consider the double refraction of the sodium light passing through the cell due to the applied electric oscillations.

According to the theory of the Kerr effect, the retardation δ, should be given by the equation

$$\delta = KD^2,$$

where κ is the specific retardation, i.e., the retardation for unit field intensity, and is connected with the wave-length λ of the light for which the double refraction is measured by the relation that

$$K = \frac{n_p - n_s}{\lambda},$$

where n_p and n_s are the refractive indices for light vibrating parallel and perpendicular respectively to the direction of the applied electric field.

The retardation of the elliptically polarized light should thus depend markedly on the relationship existing between the electric oscillations and the natural periods present in the refractive medium. Indeed, it should be zero at the position of any absorption line, then rise rapidly to a maximum on each side and then, as the frequency is still further increased or diminished from the position of the absorption frequency, it should decrease slowly towards zero.

THE ELECTRIC SPECTRUM OF WATER.

In the present experiments the maximum value of the oscillatory field E was less than 5 e.s.u. so that, if the medium were non-dispersive, we should not expect any observable effect on the application of the high frequency oscillatory

field, for we have from the measurements taken in electrostatic fields that

$$K = 4 \times 10^{-7},$$

so that the retardation in degrees is equal to

$$180 \times 25 \times 4 \times 10^{-7} = 1.8 \times 10^{-3}$$

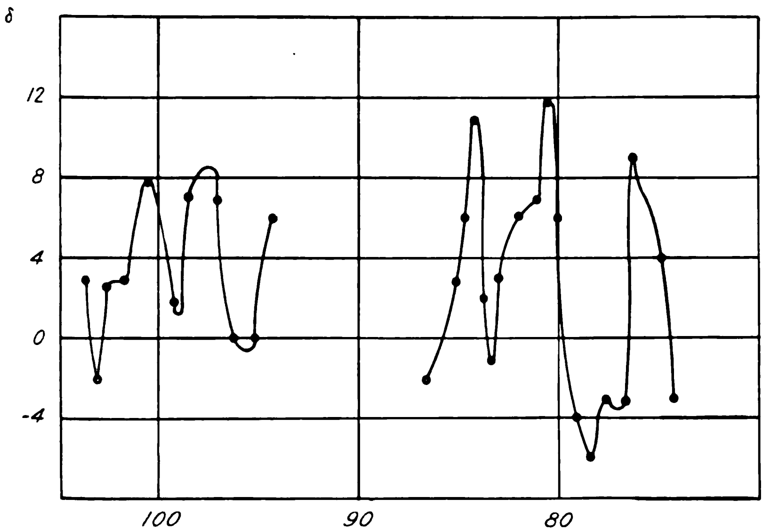
for

$$E = 5 \text{ e.s.u.},$$

a quantity which is far too small to observe.

The observed retardations δ plotted against frequency are shown in Fig. 3. The two different sets of readings, shown there, were taken for two different size cells in order to show that the effect did not depend on the constants of the circuit.

FIG. 3.



The ordinates represent the retardation, the abscissa, the wave number $\times$ 10^{-6}.

These two cells had plates of the same area but the distance between them was in the ratio of 3 to 2, so that, if the periodic character of the retardation as a function of the frequency, Fig. 3, were due to the vibration of the cell itself with a characteristic vibration and with its overtones depending on its

capacity, the periodicity of the two different sets of observations out to be in the ratio of $\sqrt{2}$ to $\sqrt{3}$, an effect, however, which is not observed.

If the retardation due to the Kerr effect were proportional to the square of the electric intensity rather than to the square of the electric induction, then as we have seen from the calculation given in the preceding paragraph, the effect would not only have been too small to observe but also we would have been unable to account for the periodicity of the retardation as a function of the frequency.

Thus from these measurements we see that the retardation is proportional to the square of the electric induction and that the medium, water, has a number of absorption lines in this region which are equally spaced on a frequency scale, the constant difference $\Delta\nu$ between the different lines being

$$\Delta\nu = 4 \times 10^6 \text{ cm.}^{-1}.$$

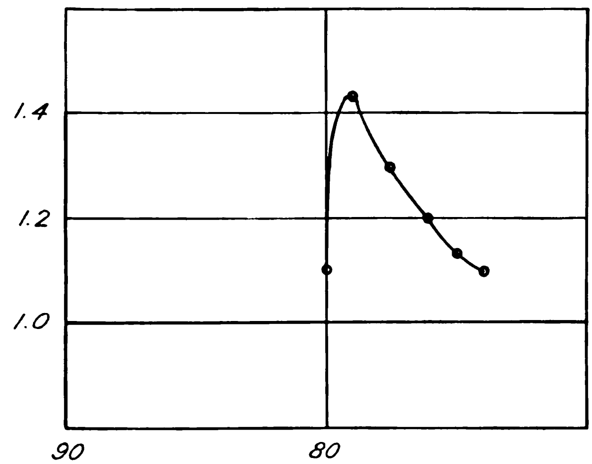
We should also expect if this phenomenon is analogous to that encountered in the investigation of the infra-red absorption bands that the electromagnetic radiation should be selectively reflected when the frequency of the incident radiation impinging on the reflecting surface of the water is nearly the same as the natural period present in the water.

In order to verify this conclusion of the electromagnetic theory, a small inductance, 2 turns of wire on a $2\frac{1}{2}$ in. mandrel, was inserted in the plate circuit of the oscillator. The inductance was placed in a long piece of glass tubing 3 in. in diameter which was surrounded by a water jacket, the water jacket being built of a piece of $3\frac{1}{2}$ in. glass tubing placed concentric with the 3 in. tube and sealed to it at the ends. The amount of radiation produced by the inductance, which was propagated down the interior of the water jacket, was measured by the heating of a thermo-couple placed at the open end of the glass tubing. The ratio of the amount of radiation measured by the thermo-couple when the water jacket was filled with water to that measured when the jacket contained no water, is given for the various frequencies comprising one absorption band in the accompanying diagram.

This diagram of the reflecting power versus frequency

gives a graph of the type encountered in the investigation of the infra-red residual rays. The reflecting power increases rapidly as the frequency is decreased towards that of the

FIG. 4.



The ordinates represent the reflecting power, the abscissa, the wave number $\times 10^{-6}$.

absorption line, reaching a maximum in its vicinity, and then decreases gradually on the other side of the line as the frequency is still further decreased.

The Correction of Astigmatism. T. J. I. BROMWICH. (*Nature*, May 12, 1928.) Sir George Airy while holding the Lucasian professorship at the University of Cambridge, 1826–28, was the first to use cylindrical lenses to remedy astigmatism. He had this kind of lenses ground for the benefit of his own vision. A later Lucasian professor, Sir George G. Stokes, 1849–1903, furnished a general theory proving mathematically "that any eye (whether long-sighted or short-sighted) can be corrected for astigmatism (as well as these other defects) by using a lens which has one face spherical and the other cylindrical."

The author proceeds to consider the saving of money and time resulting from Stokes's investigation. In consequence of his conclusions an oculist is now adequately equipped if he has 60 spherical and 40 cylindrical lenses each with one plane side, along with instruments by which to measure the angle at which the cylindrical lens gives the best correction as it is rotated about the line of sight. On the assumption of 100 such possible measurable positions, there is a total of $60 \times 40 \times 100 = 240{,}000$ combinations obtainable by the simple outfit. Thus has been made practical the prescribing of a million pairs of astigmatic lenses per year in Great Britain.

G. F. S.

SCHROT-EFFECT IN HIGH-FREQUENCY CIRCUITS.

BY

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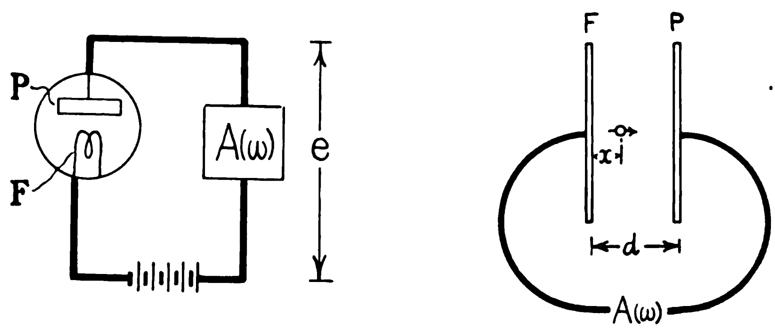
IN 1918 W. Schottky predicted theoretically that in an electrical circuit connected to a thermionic tube there would be fortuitous fluctuations of current due to the fact that the thermionic current is not continuous but is carried by discrete charges. Schottky's view of the phenomenon was a statistical one in which the behaviour and disturbance due to the individual electrons were lost. An alternative view which furnishes a clearer and more detailed picture is obtained by tracing the consequences of the passage of a single electron from filament to plate, and then to arrive at statistical values by assuming these individual processes to be random in time. Thus if the circuit connected to the tube comprises an inductance coil and condenser in parallel, the transfer of charge will excite characteristic oscillations in this circuit, and if the impacts are completely at random it follows from Rayleigh's theorem that the long-time-average of the voltage (or current) will be statistically equal to n times that due to one electron transfer, where n is the number of electrons per second. This method of treatment is physically clearer than that based upon statistical theory and Fourier-series analysis. So far as I know all of the theoretical work on the schrot-effect in thermionic circuits has considered only the gross phenomena, and the assumption underlying all of this work is that the period of the LC-circuit connected to the schrot tube is long compared with the time of passage of an electron. The purpose of this note is to indicate the character of the effect in high-frequency circuits, when this condition no longer obtains and a microscopic view of the electron's flight must be taken.

1. **Experimental Results.** — The gross equations of Schottky, with Johnson's numerical correction, have been ver-

ified by Hull and Williams,[1] and by Williams and Vincent,[2] for electronic conduction. In the first case the frequency region was about 7.5×10^5 pps (400 meters), and in the second case of the order of 5×10^4 pps (6000 meters). J. B. Johnson,[3] working in the low-frequency range of 8–6000 pps, obtained results which were discordant with the theory, the effects being higher than expected. Johnson and Schottky have endeavored to explain these low-frequency results as a "flicker" effect. At the other end of the spectrum I had made, prior to these publications, some previously unreported experiments with electrons at frequencies of the order of $1.5–5 \times 10^7$ pps (20–60 meters) and had obtained results which were consistently low by about 2–3 per cent. In this region the experimental difficulties are considerable; nevertheless the above deviation is thought to be within the error of experiment. I have also measured the effect with positive emission from a tungsten filament in an atmosphere of cæsium and found important discrepancies at quite moderate frequencies in the radio region. The following theoretical investigation originated in an attempt to account for these low values.

2. **Microscopic Theory of the Schrot-Effect.**—With reference to Fig. 1, which shows a thermionic tube connected to an electric circuit having an admittance $A(\omega)$, we wish to calculate the time-average of the square of the voltage ($\overline{e^2}$)

FIG. 1.



Thermionic tube connected to electrical circuit of admittance $A(\omega)$ for generation of schrot-noise.

[1] A. W. Hull and N. H. Williams, *Phys. Rev.*, **25**, 154, 1925.
[2] N. H. Williams and H. B. Vincent, *Phys. Rev.*, **28**, 1250, 1926.
[3] J. B. Johnson, *Phys. Rev.*, **26**, 71, 1925.

produced across the terminals of this circuit by the passage of *one electron* from the cathode F to the positively charged plate P, both of these electrodes being plane and of infinite extent. This result is most simply arrived at by the Rayleigh-Schuster [4] method of analyzing the e^2 *qua* ω distribution by means of the Fourier-integral.

As the electron moves from the cathode to the anode it induces variable charges on these electrodes. The exact relation between these charges and the position of the electron may be calculated [5] but this is not easy and it does not seem worth while to bother about it in view of the difficulty of the end-effects and other geometrical discrepancies in any practical device. As a first approximation it will be assumed that the relation is a linear one. Denoting the surface charges at cathode and anode by q_F and q_P:

$$q_F = -\frac{x}{d}\epsilon - \frac{EA}{4\pi d},$$

$$q_P = -\frac{x}{d}\epsilon + \frac{EA}{4\pi d}, \tag{1}$$

where A is the area of the part of the infinite structure under consideration and E is the potential difference between the electrodes. The second term on the right will be recognized as the *geometrical capacity* between the electrodes, and may be denoted by C_0. It may be remarked that this is not the whole capacity when there is a thermionic current in the tube limited by space-charge, but is augmented by an extra capacity effect due to the gross motion of the statistical space-charge. This "electron capacity" can be calculated and measured and a discussion of it is undertaken in a separate paper. I was originally led to look for it as the result of some mathematical work in 1920 following a remark of Prof. P. W. Bridgman. Hartmann noticed something of the kind, although his value of 180 micromicrofarads appears to

[4] See Rayleigh, *Phil. Mag.*, **27**, 466, 1889.

A. Schuster, *Phil. Mag.*, **37**, 509, 1894, or "Theory of Optics," p. 339, 2d Ed. (London: 1909).

[5] This calculation is facilitated by the work of O. Emersleben, *Ann. der Phys.*, **82**, 713, 1927.

be 100-fold too large; but Hull (*loc. cit.*, p. 158, footnote) failed to detect it, due I suppose to the fact of his working with currents limited by temperature, under which condition the electronic capacity theoretically vanishes. It would in any case be important only for very high frequencies.

The total current to the electrodes, including the normal or stationary thermionic current, corresponding to (1) is:

$$\frac{dq}{dt} = \frac{\epsilon}{d}v(t) + C_0\frac{dE}{dt} + g_0E, \tag{2}$$

where g_0 is the first-order conductance of the thermionic path $= di/dE$. This current flows through the external circuit of symbolic admittance $A(d/dt)$, hence:

$$A(d/dt) + g_0E + C_0\frac{dE}{dt} = -\frac{\epsilon}{d}v(t) = I(t). \tag{3}$$

The term on the right, in which $v(t)$ represents the electron velocity *qua* function of t, may be regarded as an *impressed current*, and if desired E may be found by a straight-forward solution of this equation. This, however, is tedious and unnecessary since we merely require E^2 and not $E(t)$, and this may be found directly from the frequency distribution of $i^2(t)$ by Rayleigh's theorem.[6] $I^2(t)$ can in turn be found by means of the Fourier-integral. In the form in which we shall use it this theorem may be stated as follows:

RAYLEIGH-SCHUSTER THEOREM.

Let two quantities $Q_1(t)$ and $Q_2(t)$, satisfying conditions, be related by means of a linear (differential) equation, Q_1 being of the nature of an effect (dependent variable) resulting from the "impressed" quantity Q_2; let $A(i\omega)$, the so-called transfer-admittance, be defined as the relation between Q_1 and Q_2 when Q_2 is of the form Exp $i\omega t$, thus $Q_1(t) = |A(\omega)|\,Exp\, i[\omega t + \varphi(\omega)]$. Then:

[6] This important theorem was called to my attention in 1920 by Prof. E. C. Kemble, in connection with the analysis of the distribution of energy in atmospheric disturbances. Somewhat similar applications to electrical problems have been made by J. R. Carson, "Electrical Circuit Theory and Operational Calculus," p. 185 (New York, 1926). It will be noticed that what Carson designates as his "corollary to Rayleigh's theorem" is simply Schuster's theorem (*loc. cit.*, p. 339).

$$\int_0^\infty Q_1(t)^2 dt = \frac{1}{\pi}\int_0^\infty |A(\omega)|^2 Q_2(\omega)^2 \cdot d\omega \tag{4}$$

where

$$Q_2(\omega)^2 = \left[\int_{-\infty}^{\infty} Q_2(t) \cos \omega t \cdot dt\right]^2 + \left[\int_{-\infty}^{\infty} Q_2(t) \sin \omega t \cdot dt\right]^2. \tag{5}$$

and if $Q_2(t)$ represents a disturbance recurring at random intervals at the average rate of n times per second, then:

$$\overline{Q_1(t)^2} = n\int_0^\infty Q_1(t)^2 \cdot dt = \frac{n}{\pi}\int_0^\infty Q_1(\omega)^2 \cdot d\omega, \tag{6}$$

or in other words the frequency distribution of the square of the total disturbance is equal to n times that of a single disturbance, and is of precisely the same form qua ω.

The application of this theorem in calculating the schrot-effect is as follows: Let $A(\omega)$ represent the transfer-admittance between the impressed current in (3) and the voltage across the terminals of the electrical circuit associated with the tube and denote by $A_a(\omega)$ the transmission factor of the amplifier generally used to produce measurable voltages. Then:

$$\overline{E(t)^2} = \frac{n}{\pi}\int_0^\infty |A(\omega)|^2 I(\omega)^2 \cdot d\omega, \tag{7}$$

or at the output terminals of the amplifier whose input is connected across E:

$$\overline{E_0(t)^2} = \frac{n}{\pi}\int_0^\infty |A(\omega)|^2 \cdot |A_a(\omega)|^2 I(\omega)^2 \cdot d\omega. \tag{8}$$

If the variation of $A(\omega)^2 \cdot I(\omega)^2$ over the transmission band of the amplifier is sufficiently small compared with that of $A_a(\omega)$, then this quantity may be taken out of the integral sign and

$$\overline{E_0^2} = \frac{n}{\pi}|A(\omega)|^2 I(\omega)^2 \int_0^\infty |A_a(\omega)|^2 d\omega. \tag{9}$$

The integral quantity may be readily determined experimentally and is simply the area under the transmission-squared curve. In order to realize the simplicity of (9) the schrot-circuit should be untuned, e.g. of the nature of a resis-

tance with the tube capacity in parallel as suggested by Williams and Vincent. In the case originally contemplated by Schottky, and used by Hartmann, Williams and Hull, and Johnson the schrot-circuit comprised an antiresonant LC combination and in this case the more difficult form (8) must be employed. Leaving aside further reference to specific circuit details the quantity $nI(\omega)^2$, which will be here called the *schrot-function*, will be more specifically considered.

3. **Temperature-limited Thermionic Current.**—The frequency distribution of $nI(\omega)^2$ may be calculated by means of eq. (5). For saturation current: $v = \epsilon E_p t/md$ $(0 < t < \tau)$, where E_p is the steady accelerating voltage across the tube and τ is the time of passage of the electron from cathode to anode. The impressed current occurring in (3) is:

$$I(t) = 2\epsilon t/\tau^2, \tag{10}$$

hence:

$$\begin{aligned} nI(\omega)^2 &= \frac{4\epsilon^2 n}{\tau^4}\left\{\left[\int_0^\tau t\cos\omega t\cdot dt\right]^2 + \left[\int_0^\tau t\sin\omega t\cdot dt\right]^2\right\} \\ &= \frac{4\epsilon^2 n}{\omega^4\tau^4}\{2(1-\cos\omega\tau) + \omega^2\tau^2 - 2\omega\tau\sin\omega\tau\} \qquad (11) \\ &= n\epsilon^2\left\{1 - \frac{(\omega\tau)^2}{18} + \frac{(\omega\tau)^4}{720} - \frac{(\omega\tau)^6}{50{,}400} + \cdots\right\} \\ &= I_s\epsilon f(\omega\tau), \end{aligned}$$

where I_s represents the average thermionic current.

As $\omega\tau$ becomes vanishingly small $f(\omega\tau)$ approaches the constant value $I_s\epsilon$ calculated by Schottky; in the general case there is a departure from the Schottky theory which increases with the frequency. The above function $f(\omega\tau)$, computed by Lt. Raymond Asserson, is shown in Fig. 2 for values of $\omega\tau$ up to 2π.

As to numerical magnitudes: For electrons,

$$\tau = d\left(\frac{2m}{E_p\epsilon}\right)^{\frac{1}{2}} = 3.4\times 10^{-8}\frac{d}{\sqrt{E_p}}, \quad \text{(sec, volt, cm).} \tag{12}$$

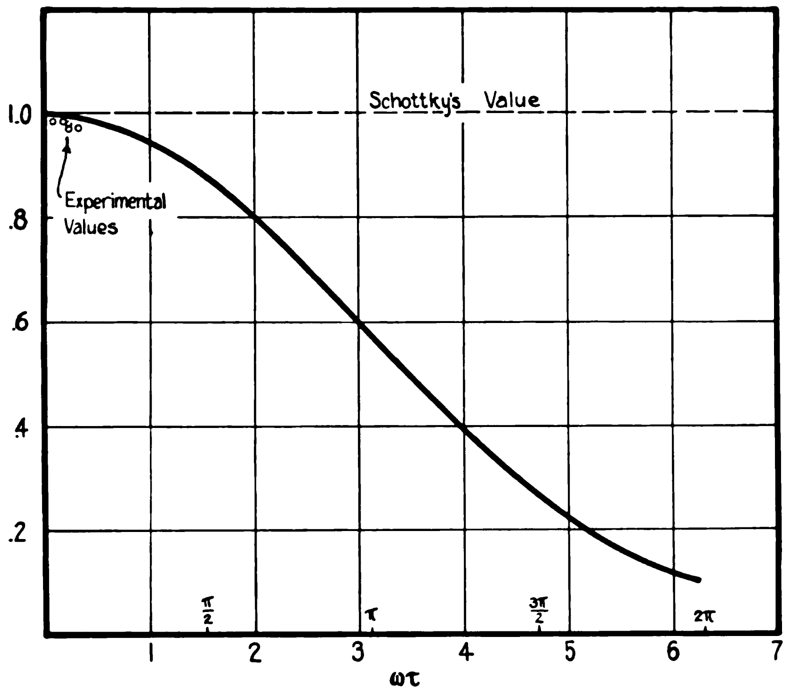
If $d = 0.6$ cm. and $E_p = 100\ v$, τ will be equal to 1.7×10^{-9} sec. For a one per cent. decrease in the schrot-effect from

the low frequency, or Schottky, value, $\omega\tau = 0.425$; a sharply tuned LC circuit would have to be tuned to a frequency of $\omega/2\pi = 4 \times 10^7$, or 7.5 meters wave-length. For positives from cæsium, with which I have made some measurements,

$$\tau = 1.66 \times 10^{-5} d/\sqrt{E_p}$$

and under the above experimental conditions, $\tau = 8.5 \times 10^{-7}$ sec. In this case a one per cent. decrease from the Schottky

FIG. 2.



Values of the schrot-function for high frequencies showing departure from Schottky's value and experimental values obtained by the author.

value would be obtained at a frequency of 8×10^4, or 3760 meters wave-length. Also since the voltage at which saturation (temperature limited) thermionic current is obtained varies with the temperature, the schrot-function decrease will set in at lower frequencies, the lower the temperature. This assumes that E_p is adjusted to a value just sufficient for saturation. It

would appear that the conditions favorable to experimental detection of this effect would be low cathode temperature and large electrode areas. Under more usual conditions its incipience would involve frequencies considerably higher than those at present employed for technical purposes. At these frequencies and voltages the finite mobilities of the electrons might demand a revision of the amplifier theory.

The experimental values obtained by me at high frequencies for electrons and positive ions from cæsium are shown by the circles in Fig. 2. These values show a drift in the direction of the theoretical curve. The absolute value is still low, due possibly to a residual error in the calibration.

4. **Schrot-effect in the Grid Circuit of a Triode.**—There are several ways in which random disturbances may occur in a three electrode tube containing impedance in the grid circuit. The first is the effect which Schottky called the "temperature effect," due to thermal agitation of the ions and electrons. If the grid circuit impedance comprises a pure high-valued resistor, we should also expect a true schrot generation at the surface of separation of the low resistance and high resistance materials.

Another effect due to impedance in the grid circuit, which however is not in any way due to generation of noise in the grid circuit *per se*, arises from feedback of energy from plate to grid through the small electrostatic capacity between plate and grid electrodes. This manifests itself in a decrease in the effective value of the admittance between the plate and filament terminals of the tube, and can be taken care of by replacing g_0 in (3) by its effective value in the presence of such regeneration, viz.:

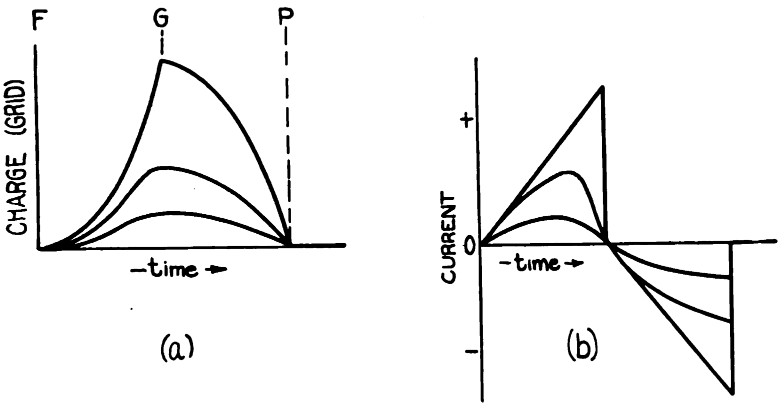
$$g_0' = g_0\left(1 + i\frac{\mu\omega C_m}{A_g + i\omega C_m}\right), \tag{13}$$

where C_m is the grid-plate capacity, A_g the admittance between grid and filament and μ the amplification factor of the triode.

Still another effect is that due to the charges induced upon the grid by the electrons passing through its meshes on their way to the plate (grid being polarized so as to eliminate actual current to it). This may be calculated by

the method of the preceding section, the induced charges being first calculated from the geometry of the tube, and the "impressed" current being then analyzed for frequency distribution by eq. (5). Without attempting to reproduce this work here, Fig. 3 illustrates in a rough way (*a*) the charge

FIG. 3.



Schrot-effect in grid circuit of a triode. (*a*) charge induced upon grid by electrons passing at various minimum distances from grid wires, and (*b*) current corresponding to this induced charge.

induced upon the grid and (*b*) the corresponding impressed current, due to electrons passing through the grid at various minimum distances from the wires. The uppermost curve represents the electrons which are reflected by the grid. As to the frequency distribution of this current-function, it will be clear that since the total induced charge is zero, the schrot-function will vanish at low frequencies, will increase with frequency and have maxima at $\omega\tau = n\pi/2$ (odd n), and minimum for even n. Since in the tube the divergence of the total current is zero, the change induced on the grid will affect the schrot-effect in the plate even though the grid impedance is zero. This shielding effect will vanish at low frequencies, but will modify the Fig. 2 schrot-function in a triode at high frequencies.

December 1927.

Quantitative Determination of Nickel in the Presence of Chromium. When alpha benzildioxime is added to the ammoniacal solution of a nickel salt, the nickel is precipitated quantitatively as the nickel derivative of the dioxime. However, if chromic salts are also present, they contaminate the precipitate even when tartrates or citrates have been added to the solution. FREDERICK G. GERMUTH of the Department of Public Works of Baltimore (*Chemist Analyst*, 1928, *17*, No. 2, pages 3, 7) finds that the addition of a minute quantity of cupric ammonium chloride to the solution prior to precipitation of the nickel prevents occlusion of chromium in the nickel precipitate, and thus increases the accuracy of the determination. J. S. H.

Hydrogen Peroxide. A. C. CUTHBERTSON, G. L. MATHESON AND O. MAASS of McGill University (*Jour. Am. Chem. Soc.*, 1928, *50*, 1120–1121) find that pure hydrogen peroxide has a melting point of — 0.89° C., and a density of 1.4649 at 0° C. J. S. H.

ON RELAXATION OF ELECTRIC FIELDS IN KERR CELLS AND APPARENT LAGS OF THE KERR EFFECT.

BY

J. W. BEAMS, PH.D. AND ERNEST O. LAWRENCE, PH.D.

INTRODUCTION.

WHEN an electric field is impressed between parallel plates immersed in carbon bisulphide it is found that the liquid becomes doubly refracting. This phenomenon, called the Kerr Effect, has been known for a long time and has been used in various ways in optical investigations involving very short time intervals. Recently one of the authors [1] made use of a modification of the method of Abraham and Lemoine [2] in a study of the relative times of appearance of spectrum lines in spark discharges and later [3] carried out some experiments which indicated that in some liquids the Kerr effect lags behind a rapidly changing electric field. During the past year the authors [4] studied the photo-electric effects produced by short flashes of light and also investigated in further detail the apparent lags of the Kerr effect in various liquids. The present work is a continuation of these experiments.

EXPERIMENTAL ARRANGEMENT AND THEORY OF THE METHOD.

The experimental arrangement for the study of lags in the Kerr effect and for the production of short light flashes centers around two Kerr cells, K_1 and K_2, placed between crossed Nicol prisms, N_1 and N_2. The normals to the surfaces of the plates of one cell are at right angles to the normals to the surfaces of the other pair of plates and both sets of normals make angles of forty-five degrees with the electric vector of the plane polarized light passing between the plates from N_1.

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[1] Beams, *Phys. Rev.*, Vol. 28, p. 475, 1926.

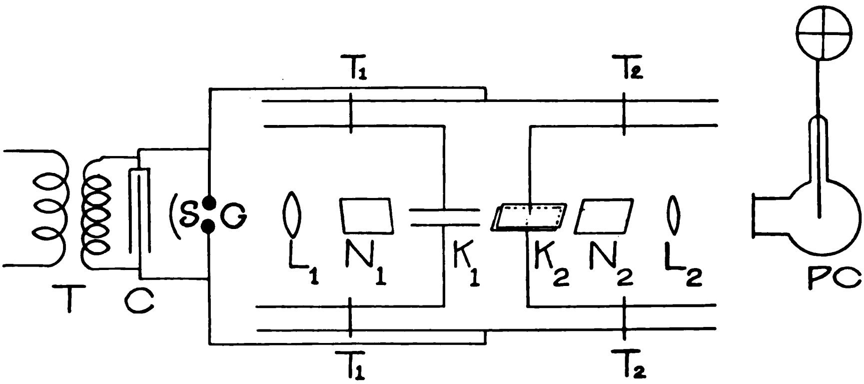
[2] Abraham and Lemoine, *Comp. Rend.*, Vol. 130, p. 245 (1900).

[3] Beams and Allison, *Phil. Mag.*, Vol. 3, p. 1199, 1927.

[4] Lawrence and Beams, *Proc. Nat'l. Acad.*, Vol. 13, p. 207 (1927). Beams and Lawrence, *Proc. Nat'l. Acad.*, Vol. 13, p. 505 (1927).

As the diagram indicates, (Fig. 1), the plates are attached to the spark gap SG by wires of variable length T_1T_2, the spark gap being also the source of light for the Nicol prism-Kerr cell optical system.

FIG. 1.



Prior to the discharge of the spark the potential difference applied across the spark gap by the transformer T and condenser C is also impressed across K_1 and K_2. Being at right angles to each other, however, the ellipticity of the light produced by the double refraction in K_1 is compensated by the opposite double refraction in K_2 and therefore the light emerges from K_2 plane polarized and unable to pass through N_2. On discharge of the spark a steep discharge wave is propagated along the wires and at a time after the beginning of the spark discharge equal to the wire path divided by the velocity of light the cells begin their discharge. Thus, for example, if the leads to K_2 are longer than the leads to K_1, K_1 will begin discharging before K_2 and during the period when the fields between the plates are unequal the light will be elliptically polarized and a portion of the light from N_1 will emerge from N_2.

The intensity of the light emerging from the Nicol N_2 is a function of the differences of the birefringence in the two cells and, indeed, because of the small values actually operative in the present experiments, the intensity of the light is proportional to the square of the differences in the retardations of the electric vector. The double refraction being

proportional to the square of the electric field between the cell plates, it follows that the intensity of the light I is

$$I = I_0(V_1^2 - V_2^2)^2,$$

where V_1 and V_2 are the voltages across K_1 and K_2 at any time t and I_0 is the proportionality constant which of course depends on such factors as the Kerr constant of the liquids, the size of the Kerr cells, the intensity of the light entering N_1, etc.

In order to obtain a qualitative theory of the action of the electro-optical arrangement it is assumed that the electric field between the Kerr cell plates disappears exponentially in time after the discharge wave strikes the cell. Thus, if the leads to the Kerr cells differ in length by l cms. such that K_1 begins its relaxation of the electric field at time t_1 and K_2 at a corresponding time $t_2 + t_l$, where $t_l = l/c$, c being the velocity of light, the intensity of the light emerging from N_2 at any time prior to t_1 will be zero (for the cells are arranged so that each shall compensate the effects of the other when both are charged to the same voltage) and in the time interval t_1 to $t_1 + t_l$ the intensity will be

$$I_{t_1}^{t_1+t_l} = I_0 V^4(1 - e^{-2\alpha_1 t})^2,$$

and for all values of t greater than $t_1 + t_l$ the intensity of the transmitted light will be proportional to

$$I_{t_1+t_l}^{\infty} = I_0 V_0^4(e^{-2\alpha_1 t} - e^{-2\alpha_2 t})^2,$$

where of course α_1 and α_2 are the exponential time constants which determine the rapidity of relaxation of the electric field in K_1 and K_2, respectively.

The total flux of light energy through N_2 consequently is

$$E = E_0 \int_{t_1}^{t_1+t_l} (1 - e^{-2\alpha_1 t})^2 dt + E_0 \int_{t_1+t_l}^{\infty} (e^{-2\alpha_1 t} - e^{-2\alpha_2 t})^2 dt,$$

which reduces on integration to

$$E = E_0 \left[t_l + \frac{\alpha_2}{(\alpha_1 + \alpha_2)\alpha_1} e^{-2\alpha_1 t_l} + \frac{\alpha_1 - 3\alpha_2}{4\alpha_1\alpha_2} \right]. \qquad (1)$$

If the Kerr cells are identical in shape and are placed symmetrically with respect to other parts of the electrical circuit their time rates of discharge are equal, i.e.,

$$\alpha_1 = \alpha_2 = \alpha.$$

For such a special case, equ. (1) reduces to

$$E = E_0 \left[t_l + \frac{1}{2\alpha} (e^{-2\alpha t_l} - 1) \right]. \tag{2}$$

Clearly for $t_l = 0$, that is, when the wires connecting the cells to the spark gap are of the same length the birefringence in the two cells compensate for all time and the flux of light from N_2 is zero.

It is equally evident from equation (1) that in case $\alpha_1 > \alpha_2$ the flux of energy from N_2 is not zero when $t_l = 0$ and indeed the energy flux is not even a minimum. The value of t_l for which E is a minimum is of course the value which satisfies the condition,

$$\frac{dE}{dt_l} = 0$$

and is

$$t_m = \frac{1}{2\alpha_1} \log \left(\frac{2\alpha_2}{\alpha_2 + \alpha_2} \right). \tag{3}$$

Thus, if the voltages across the plates of the Kerr cells decrease exponentially at different rates typified by the constants α_1 and α_2, the maximum extinction of the light is attained when the wire paths to the two cells are unequal by the amount l cms. where

$$l = ct_m.$$

Substituting this value of t_m in equ. (1) we have an expression for the magnitude of the flux of energy through the shutter when the wire paths are arranged to give greatest extinction, viz.,

$$E_m = \frac{1}{2\alpha_1} \left[\log \left(\frac{2\alpha_2}{\alpha_1 + \alpha_2} \right) + \frac{\alpha_1 - 3\alpha_2}{2\alpha_2} + 1 \right]. \tag{4}$$

It is easy to see, moreover, that different rates of discharge of the Kerr cells irrespective of the mode of discharge, would always be in evidence by such lack of complete extinction of the light through the optical system.

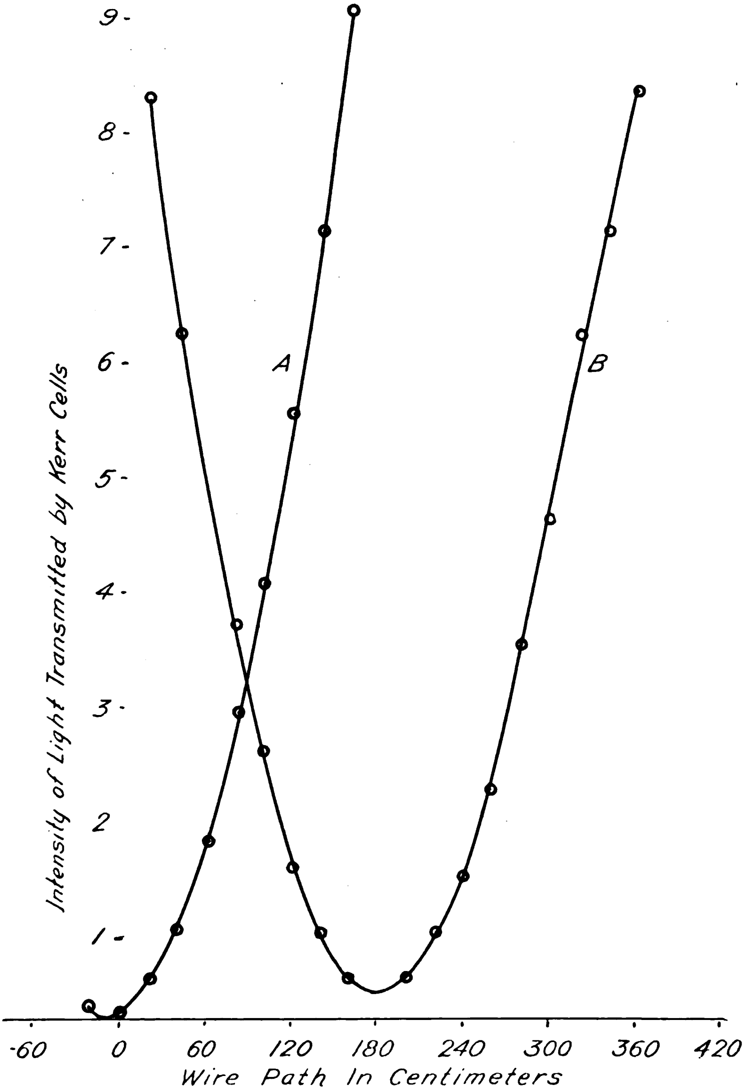
EXPERIMENTAL OBSERVATIONS.

Fig. 2 exhibits results which are typical. Curve A is a plot of the photo-electric current produced in a photo-cell PC due to light emerging from N_2 corresponding to various differences of lengths of lead wires to K_1 and K_2 when K_1 and K_2 are identical in dimensions and symmetrically placed in the circuit. The photo-electric current, and therefore the amount of light emerging from N_2, is zero when the wires to the two cells are of the same length, the extinction of the light being perfect within the experimental error. Curve A is the theoretical variation of the flux of radiation as calculated from equ. (2) assuming α to be 10^8; the circles represent the experimental observations. The close agreement of the data with the curve cannot be regarded as definitely indicating that the voltage across the Kerr cell plates drops in an exponential manner; an appreciably different type of discharge would give rise to very similar data. It may be inferred with considerable confidence, however, that the discharge takes place in less than 10^{-8} sec.

The circles of Curve B are a similar plot of the observed amounts of light passing through the optical system for the same Kerr cells with a third cell K_3 placed in parallel with K_2. The plates of K_1 and K_2 were 8 cms. long, 1 cm. wide and were separated by 0.5 cm. of carbon bisulphide. K_3 was 15 cms. long and otherwise similar to K_1 and K_2. The system $K_2\,K_3$ had a capacity therefore of about 3 times the capacity of K_1. The differences of capacity of the two systems caused K_1 to discharge more rapidly than K_2. This difference of rates of discharge produced the shift of the wire path difference for minimum light transmission from zero to 180 cms. and also destroyed the ability of the shutter to extinguish completely the light. Assuming that the cells discharge exponentially with time constants of $\alpha_1 = 10^8$ and $\alpha_2 = \frac{1}{3}\cdot 10^8$ it is computed from equ. (3) that the wire path differences for maximum extinction is the observed 180 cms. However, the

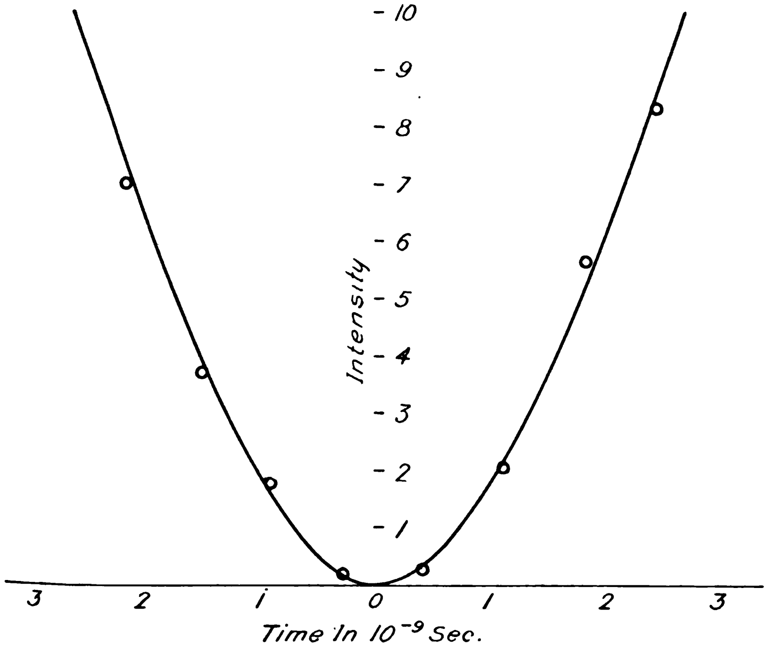
variation of the flux of light through the optical system with different relative wire paths to K_1 and K_2 is very much different from the variation to be expected from equation (1). Indeed, the minimum flux of light is less than a tenth of the

Fig. 2.



amount predicted by equ. (4). It appears therefore that an exponential discharge cannot account quantitatively for the action of the Kerr cells. The fact that there are very marked shifts of relative wire paths for maximum extinction of the light, the light extinction nevertheless being so nearly complete, indicates that the discharge is less rapid initially and more rapid in its later stages.

FIG. 3.



The dependence of the rate of discharge on the capacity of the cells suggested that cells of smaller capacities would yield much more rapid relaxations of the birefringence. Cells having plates 2 cms. long with otherwise similar dimensions to the 8 cms. cells gave the data of Fig. 3 where the curve is the theoretical curve, [equ. (2)] with $\alpha = 2 \cdot 10^8$ and the circles represent the experimental observations. Also, inserting correspondingly small capacities in parallel with the cells gave rise to differences of wire paths to the two cells for extinction of the light which interpreted by equ. (3) indicated

such larger values of α and therefore more rapid decay of the double refraction. However, the change in α with change in capacity was not linear and seemed to approach a limiting value for cells of these dimensions.

DISCUSSION.

The way in which the Kerr cells discharge clearly depends not only on their capacities and the inductance and resistance (resistance being negligible) of the connecting wires but also on the rate of fall of voltage across the spark gap and the steepness of the discharge wave which travels along the wires from the spark gap to the Kerr cells. A very interesting research having an important bearing on these considerations has recently been carried out by Rogowski, Flegler and Tamm.[5] They have studied the form of wave fronts traveling along parallel wires 60 meters long resulting from suddenly impressing a voltage at one end by closing a switch, a Braun tube oscillograph being attached at the other end. Their photographs show in most cases wave fronts steeper than they were able to detect, although slopes of $3 \cdot 10^{-8}$ sec. should have been quite evident. On increasing the speed of the time axis such as easily to resolve less than 10^{-8} sec. they found that the wave fronts were even steeper than 10^{-8} sec., although a slight slope was in evidence. The small slope which they observed was probably largely due to the finite rate of charging of the deflecting plates of the oscillograph having capacities of about 6 cms. They concluded that the capacity of the plates was negligible because it was observed that placing a capacity of 10 cms. in parallel with the deflecting plates produced no appreciable change in observed effects. However, this test was carried out using a slower time axis which was incapable of resolving effects of 10^{-8} sec. duration. Even with the slower time axis a very marked effect was produced when plates of 20 cms. capacity were inserted in parallel with the deflecting plates, the magnitude of the effect being such as to make it quite evident that the capacity of the oscillograph determined the steepest observed slopes. Their very fine technique led also to a study of the time of break down of spark

[5] Rogowski, Flegler and Tamm, *Archiv. für Elektrotechnik*, Vol. 18, p. 479 (1927).

gaps. They found that the voltage across a spark gap drops to a small value in less than 10^{-8} sec. even when the platinum points of the spark gap were 6 cms. apart.

The general conclusion to be gained from their research therefore is that the wave fronts traveling down the wires in the present experiments had slopes extending over less than 10^{-8} sec. and consequently that the inductance of the lead wires and the capacity of the Kerr cells determined largely the nature of the fall of voltage across the plates. If the effect of resistance of the lead wires were large compared to the effect of their inductance the voltage would have dropped exponentially as has been assumed above in the theory of the action of the optical system. A simple computation shows, however, that the resistance of the wires was negligible and therefore the discharge, instead of falling off exponentially, because of the inductance, was less rapid initially and more rapid in its later stage. As pointed out in an earlier paragraph this estimate of the nature of the discharge is in accord with a reasonable interpretation of the experimental data of curve *B*, Fig. 2.

In a study of the photo-electric effects produced by flashes of light emerging from the electro-optical shutter corresponding to various differences of wire paths to the two cells, it was concluded that flashes as short as 10^{-10} sec. duration were produced. In view of the present definite evidence for the very appreciable discharge rates the former conclusion must be modified. The shortest flashes produced were more probably of the order of magnitude of 10^{-9} sec. duration.

Experimental observations in the past which have been interpreted as evidence of a lag of the Kerr effect behind the electric field are, on the basis of the present work, more probably due merely to the different capacities of cells containing dissimilar liquids having various dielectric constants.

In 1913 Gutton [6] carried out some experiments which were interpreted as indicative of very considerable lags of the Kerr effect in various liquids. He arranged two Kerr cells with their plates at right angles to each other between crossed

[6] Gutton, *Jour. d. Phys.*, Vol. 3, p. 445 (1913).

nicols and adjusted the distance apart of one of the pairs of plates so that the Kerr effects produced in each cell were compensated, thereby extinguishing the light observed through the crossed nicol. He found that, with different liquids in the two cells, although their Kerr effects compensated for equal applied static voltages, extinction of the light was not attained when sufficiently high frequency alternating voltages were used. He found it necessary to increase the field in one of the cells by a readjustment of the separation of the plates in order to regain extinction. This was interpreted as indicating that the Kerr effect in one of the liquids was unable to build up as rapidly as the changing electric field and therefore required a larger capacity, i.e., greater electric field to produce sufficient birefringence to compensate the double refraction in the other cell. It is more probable that the cell of larger capacity did not charge up to the same potential as the smaller cell and for this reason alone compensation was not attained at high frequencies.

The two cells containing different liquids when adjusted to compensate each other with equal static potential differences across the pairs of plates will have capacities proportional to the ratio of the dielectric constant to the Kerr constant of the liquids. This is true because a large Kerr constant requires a small cell to produce a given birefringence and for given dimensions of the plates the capacity of course is proportional to the dielectric constant. It is to be expected therefore that a cell containing a liquid having a large value for this ratio would have a relatively slow charging and discharging rate and would apparently exhibit a lag of the Kerr effect relative to the Kerr effect in the other cell containing a liquid having a smaller value for this ratio. This is really what Gutton observed as the table below indicates.

Pairs of Liquids.	Ratio $\frac{\text{Dielectric constant}}{\text{Kerr constant}}$.	Lag of Kerr Effect.
Nitrobenzene	.0046	0.6 (10^{-8} sec.)
Bromonapthalene	.016	
Nitrobenzene	.0046	1.4 (10^{-8} sec.)
Carbonbisulphide	.026	
Carbonbisulphide	.026	1.7 (10^{-8} sec.)
Toluene	.10	

The first column lists the pairs of liquids examined, the second column records the ratios of the dielectric constant to the Kerr constants (which are proportional to the capacity of the cells containing the liquids) for the various liquids and the third column contains the observed apparent excess lag of the Kerr effect in the second liquid relative to a lag in the first. It is seen that in all cases the cell having the larger capacity contained the liquid exhibiting the larger apparent lag of the Kerr effect. Consequently, it is to be concluded that his observations cannot be regarded as measures of lags in the Kerr effect but are the results of capacity effects.

The observations in the past [3] using the technique involved in the present experiments which were interpreted as observations of lags of the Kerr effect are quite evidently also due to capacity effects. The extinction of the light passing through the optical system was so nearly perfect in experiments of this sort—although the rates of discharge were sufficiently different to require very marked differences in wire paths to the cells to obtain extinction—that a relative lag of the Kerr effect in one of the liquids presented itself as the most reasonable interpretation of the phenomenon. However, the present work makes such a view quite out of the question.

There is, therefore, at the present time no experimental evidence for the existence of a lag of the Kerr effect behind rapidly changing electric fields. This conclusion is quite in accord with prevailing theories of the Kerr effect which predict such lags to be considerably less than were detectable by any of the mentioned experiments.

SLOANE LABORATORY,
YALE UNIVERSITY,
June 12, 1928.

A New Art in Electric Lighting. W. E. Bush. (*Electrician*, March 30, 1928.) To the Exposition des Arts Décoratifs held in Paris in 1925 can be traced the inception of a new movement in the production of illumination. Where fittings were used at all they were often made of frosted glass in flat sheets, but in many cases there were no fittings the arrangements for illumination having been built into the structure of the building. In London such lighting is used in the Café Royal, The Trocadero and elsewhere. A good application is on the " Ile de France " where most staterooms and saloons get their light from glass panels or hidden sources. There are but few suspended lighting fixtures on the vessel. " The magnificent dining saloon is flooded with light from moulded glass panels, slightly yellow tinted, which are let into the ceiling and upper walls. Behind each panel is fixed a 300 watt gas-filled lamp, and the intensity of illumination is so high that an impression of brilliant sunlight is created. The total lighting load for this room alone is 50 kilowatts. The lighting of some corridors is particularly interesting, where, instead of employing lamps totally concealed behind a cornice, narrow frosted glass strips are fixed along the wall at picture-rail height, and the lamps placed behind the glass. Even the cross in the beautiful chapel is of moulded glass lighted from behind."

In Paris the Galeries Lafayette have a canopy consisting of glass panels behind which are white and colored lamps. From a central switchboard color changes are produced that cause beautiful effects. The new type of lighting is in evidence elsewhere in Paris.

Thus a high total intensity of illumination is obtained with low brightness of the illuminating surface. This comes from the larger area of glass used in comparison with the usual types of lamp and from the employment of a larger number of lamps of moderate candle-power rather than a small number of high intensity. The new kind of illumination must be designed at the time of the planning of the building. It cannot be subsequently imposed as an afterthought. Its introduction may well mark the passing of the purely utilitarian conception of illumination and the substitution of artistic standards.

G. F. S.

EFFECT OF METHODS OF DEMAGNETIZATION ON THE ENERGY REQUIRED TO MAGNETIZE STEEL.

BY

JOHN D. BALL, B.S., E.E., Ph.D.

It has been observed for a number of years that the hysteresis losses in magnetic materials have been indicated to be less when tested by means of alternating current than when tested by the direct current or step-by-step methods. For example, the hysteresis loop taken by the well-known means of measuring flux changes by a ballistic galvanometer frequently indicates more hysteresis loss than when the same specimen is tested by methods where the material is continually going through a cyclic state as in the separation method such as testing at various frequencies or by methods using slow cycles.

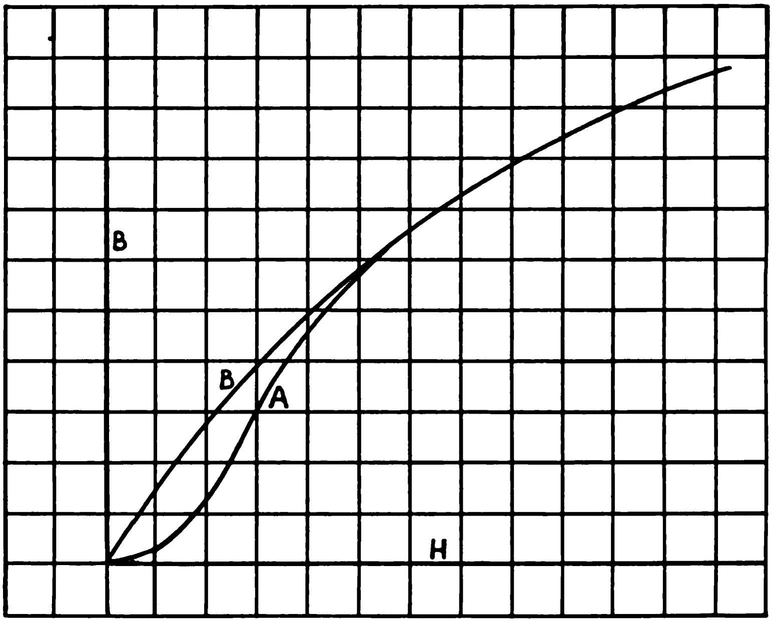
When using the step-by-step methods it is customary to make the observations necessary to obtain a half loop and let the other half be obtained by draftsmanship. However, when data for the entire loop are taken the loop does not always close at the top. Obviously many discrepancies are due to variations in the materials themselves and in the inaccuracies of testing, especially in such step-by-step methods which involve cumulative errors.

It is also a well-known fact that at low flux densities, when plotting B and H values, the resulting graph is a reverse curve with two decided bands. The curve shows that the increase of flux density with increasing field or applied magnetomotive force is not as rapid at the beginning of the magnetization as later on when the flux density increases very rapidly with increasing field until the further increase of flux density is curtailed by approaching saturation. This fact is illustrated in Fig. 1.

It is to be noted that at very low flux density the B–H curve does not show correspondingly low flux changes with increasing H as indicated by curve "B," but when a sufficient number of observations are taken the characteristic curve

of any magnetic material is such as indicated by curve "*A*," which is a typical *B–H* curve.

FIG. 1.



Curve *A*, typical *B–H* curve for a magnetic material. Curve *B*, *B–H* curve when flux is passing through zero at $H = O$ from negative values of *B* and *H*.

Not long ago an explanation suggested itself that this first bend of curve "*A*" or, more definitely, the considerable field strength required to build up the flux density might be due to one, or both, of two things. First, the static inertia of magnetic elements involved might be such that a force must be expended to start the motion of the molecules or magnetons or what-not, in the same manner as energy is required to bring any body from rest to motion. After the motion is well under way further increases of *H* would result in a more rapid increase of flux values, or, to satisfy other theories of magnetism, a force would be required to change the velocity or direction of the elements involved. Another explanation is that the continuous motion of magnetic elements into different states or arrangements may be accomplished with less

energy than when the change of motion or state is brought about by a continuous starting and stopping, as in a step-by-step method, which is employed in order to obtain the various points the loci of which determine the *B–H* curves. This viewpoint has an analogy in the well-known difference between starting and running friction.

If these assumptions be true, to bring a demagnetized material to a given induction might require more energy if magnetized from a state of rest than would be required to bring the material from zero flux to the same induction if a change of flux is already taking place in that direction, as would be the case if the magnetism started from some flux density of negative or opposite polarity.

Referring again to Fig. 1, curve "*A*" is the typical form when started at zero induction, the specimen having been demagnetized, whereas, if the specimen should have a polarity in the opposite direction of such a value that the flux would have a zero value when *H* is also zero and the process continued without stopping, the resultant conditions in the specimen might be as represented by curve "*B*."[1] The energy of static inertia or the additional energy to start and accelerate the movement or to change the direction and velocity of movement or the energy representing the difference between running and starting friction may be determined by the area between the two curves "*A*" and "*B*."

SUGGESTED TESTS.

Methods of attack would include:

1. The taking of a number of *B–H* curves starting at zero flux and zero field, having previously demagnetized the specimen.
2. The taking of a number of *B–H* curves starting at a negative value of flux density and a negative field, selecting such values as would cause the curve to pass through zero flux and zero field simultaneously and then to continue the observations.

[1] In order to obtain a hysteresis loop where zero flux occurs simultaneously with zero "*H*" it is necessary to select conditions where one of the maximum flux values is greater than the maximum flux value at the opposite polarity. Such a loop is unsymmetrical. See "The Unsymmetrical Hysteresis Loop," John D. Ball, *Trans. A. I. E. E.*, Vol. XXXIV, Part 2, 1915, pp. 2275–2297.

3. The taking of a number of B–H curves wherein each point is taken by a single step from zero flux and field to the point in question and also to reach the same value of H by several steps, observing the flux changes and comparing the sum of the flux changes with the flux change when arriving at the same H value in a single step. If additional energy is required to start the motion producing flux change, at each step, then the sum of the flux changes to arrive at a definite H value will be less as the number of steps is increased.
4. The taking of a number of hysteresis loops proceeding step by step, using as few steps as possible to determine properly the graph, and repeating the tests taking an increasing number of points. Comparison of the loops might show an increased area with an increased number of points.
5. The analyses of such curves as may be obtained with a view of determining any empirical equations which might satisfy the curves.

There are some practical difficulties and limitations involved in the above outline of suggestions which may be mentioned here:

1. First and foremost we must consider just what consists of the right conditions in a magnetic specimen which will give us zero flux and zero field or proper demagnetization. Demagnetization is a study in itself and magnetic curves are governed not only by the specimen being apparently demagnetized but also by previous magnetic history with special reference to how demagnetization was accomplished.[2]

2. The measurements are of small quantities and include not only properties of materials but differences between apparent properties of materials under various conditions. This means that small measurements are involved which require delicate instruments and, as the differences are small percentages of the measured properties, accurate methods and technique are demanded.

3. The magnetic creepage is most noticeable at low densities and may be a considerable factor. It is to be remembered

[2] "The Best Method of Demagnetizing Iron in Magnetic Testing," C. W. Burrows, *Bulletin of U. S. Bureau of Standards*, Vol. 4, No. 2, pp. 205–274.

that the ballistic galvanometer measures only the flux change occurring within one quarter of the time of its natural period. Consequently it must be determined what creepages are involved and if flux changes occur after the quarter period of the galvanometer they must be measured.

4. The damping of the galvanometer itself must be determined. If a number of steps are taken to reach a definite value of H and compared with the flux value of reaching the same H in a single step, we must be sure that the several dampings of the galvanometer do not appreciably affect the observations.

5. Step-by-step methods in themselves are not as accurate as where curves are determined by obtaining each point directly from a maximum flux density or a reference point. All continuous step methods are susceptible to this cumulative error.

6. There is a fundamental difficulty due to the fact that we are interested in values of B and H when passing through points without stopping, and stopping is necessary to determine the points by the usual ballistic galvanometer methods.

7. In determining the path of the B–H curve where energy may be required to start and bring about the magnetization a difficulty arises in making the proper interpretation of the results obtained, as it is quite possible that this energy may be stored in the magnetic material and discharged after the field strength, or corresponding current, has reached its value at the end of each step. This discharging of energy may be absorbed by raising the flux to a higher value than is immediately reached when the current arrives at the point in question. This is a form of magnetic creepage and may occur in time to be registered by the galvanometer or may continue to occur after its "swing" or quarter period. Even if this be true to a certain extent we still have the consideration of the difference between starting and running friction, which energy is not recovered, as it is dissipated in heat.

MATERIALS TESTED.

For the purpose of the present tests two rings were selected, one of which was of standard iron and the other silicon steel.

The principal measurements are:

Outer diameter 8.9 cm.
Inner diameter 6.87 cm.
Mean length of magnetic circuit 24.77 cm.
Thickness of sheets 0.036 cm.

Windings:

1. Potential, or galvanometer, coil, 200 turns No. 20 double cotton covered wire, dia. = 0.081 cm.
2. Magnetizing coil, 100 turns No. 16 double cotton covered wire, dia. = 0.13 cm.

Sample *A*:
Standard iron. Annealed. Sp. gr. (assumed) 7.7.[3]
Wt. = 421.74 grams.

Sample *B*:
Silicon steel. Approximately 3.5 per cent. silicon. Annealed.
Sp. gr. (assumed) 7.5.[3]
Wt. = 422.75 grams.

The apparatus and methods used during the tests are so generally known as to require no description here.

DEMAGNETIZATION.

A considerable number of tests were made to determine exact data as to the *B–H* curves which would be obtained when various methods of demagnetizing were used.

The method which is doubtless the most reliable and is used as the standard of comparison is that recommended by the U. S. Bureau of Standards. The method is described in the Bureau's *Bulletin*.[4]

> "The demagnetization should be accomplished by a current reversed at the rate of approximately one cycle per second, while gradually diminished in such a way that the rate of decrease of the induction is as nearly as may be uniform, ... The initial demagnetizing current should be sufficient to carry the induction beyond the knee [5] of the *B–H* curve, and the final current should be

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[3] In accordance with specifications of the American Society for Testing Materials.

[4] *Ibid.*, page 274.

[5] It is unfortunate that the Bureau refers to the "knee" of the *B–H* curve. This apparent bend, often called the "knee" of the curve, is not a magnetic

not greater than the smallest magnetizing current to be used."

In the subsequent discussion we will refer to this method as Method "*A*."

In the *Bulletin* already referred to, attention is called to the fact that zero flux and zero field may be obtained by various methods, but the method used will affect the nature of the *B–H* curve taken after the various methods of demagnetization.

In investigating the possibilities of inertia or friction differences governing the shape of *B–H* curves, demagnetizing by other methods which gave the same zero flux-zero field or "state point" was performed.

MAGNETIC ELASTICITY.

If a material is magnetized and the field be removed, the magnetism will fall to a flux value indicated on the loop as the residual magnetism or the point where the curve crosses the axis of zero field. However, if a negative value of current equal to the coercive force were applied either by steps or by a single throw, the flux value would be brought to zero but upon removing the current the flux will increase toward the same direction or polarity whence it came. The flux apparently "springs back" to a certain extent toward the value of the residual magnetism. As this characteristic has not been named, the designation "magnetic elasticity" strongly suggests itself.

Tests, made by various investigators and during the process of the present inquiry, show that by using an amount of negative current in excess of the coercive force a definite amount of negative flux density may be reached which, upon release of the current, results in the flux reversing and coming to an exact zero value the same as when demagnetizing by the slow reversals,[6] but when the specimen is again magnetized

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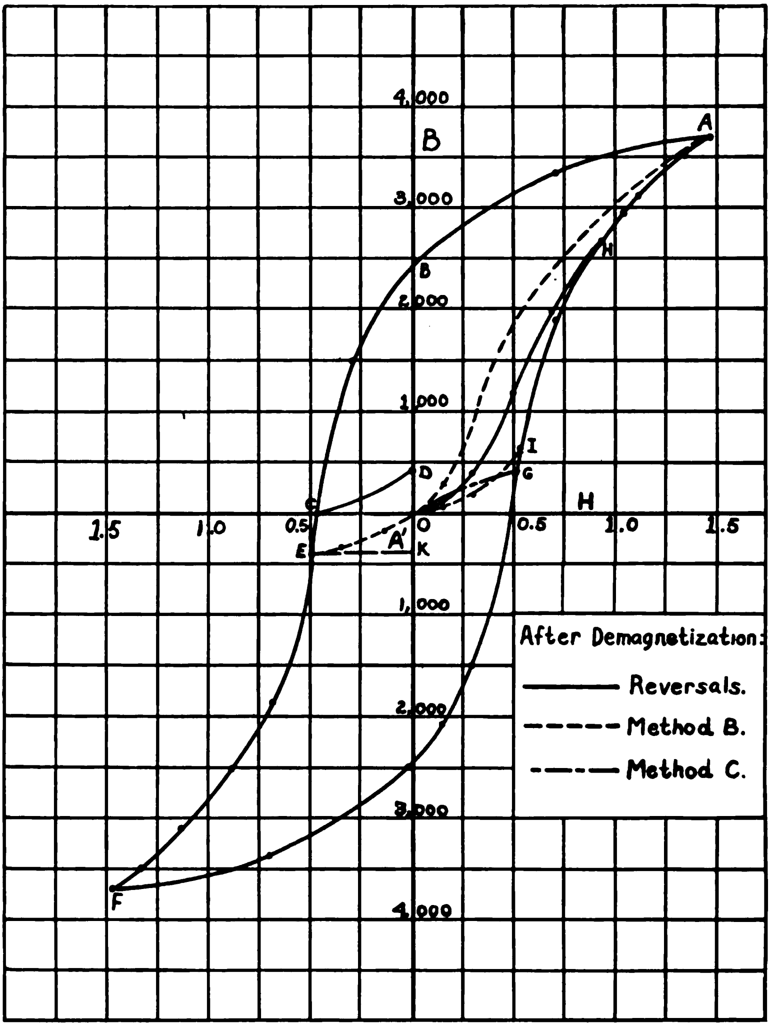
property but is an artificial condition which apparently occurs at any number of different values of flux density which can be brought about by plotting curves to different scales. The "knee" is a function of the scale selected. See "Some Notes on Magnetization Curves," John D. Ball, *Gen. Elect. Review*, Vol. XVIII, Jan., 1915, pp. 31–35.

[6] This is shown by Messrs. Smith and Hammond in "Neutral Magnetization in Iron," *The Physical Review*, Vol. XV, April, 1920, pp. 249–255.

we find very different results, which depend upon the method by which the zero flux value was obtained. For convenience

FIG. 2.



B–H curves after various methods of demagnetization.

of reference we will call the method of demagnetizing by the application of the negative current Method "*B*."

A third method of obtaining zero flux is to obtain a flux density and then reverse the flux to the same density of the opposite polarity. Then by applying a proper amount of positive current greater than that of the coercive force, the removal of this current results in the flux springing back to zero. If now the material be magnetized in the positive direction, a still different *B–H* curve results from that obtained by the above described process. This last method is the same in effect as Method "*B*" except the further magnetization is performed at the opposite polarity. We will call this Method "*C*."

These methods may be shown by reference to Fig. 2. The hysteresis loop is the path *A–B–C–E–F–G–I–H–A*. *O–B* is the residual magnetism and *O–C* the coercive force. If the material is demagnetized by current reversals, the "state point" of zero flux and zero field or current is reached at point *O*. If now the *B–H* curve be determined, it will follow a path such as represented by *O–H–A*.

If from point *A* the curve *A–B–C* be determined, upon removing the current the path of the curve is from *C* to *D*. Demagnetizing by Method "*B*" consists of continuing the curve *A–B–C* to *E*. Upon removing the current the flux path will be *E–O*. Now if the *B–H* curve be determined it will follow path *O–A*. Demagnetizing by Method "*C*" consists of curve *A–B–C–E–F–G* and releasing current continuing curve from *G* to *O*. If now the *B–H* curve be determined, we will obtain curve *O–I*.[7]

A THEORY OF MAGNETIC ELASTICITY.

Theoretical considerations indicate magnetic elasticity is to be expected if our theory regarding the first bend in the *B–H* curve is correct.

This also satisfies the conditions that when demagnetizing by alternating current we obtain consistent amounts of residual magnetism. Also such a situation is consistent with the observed facts that the plotted data do not always give us a closed loop.

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[7] There are, of course, other methods of demagnetization, such as diminishing amounts of applied alternating current. See G. F. C. Searle, *Proc. of Inst. of Elect. Engrs.*, Part 170, 1904, pp. 55–118, and "Demagnetization of Iron," A. W. Smith, *Physical Rev.*, Vol. X, Sept., 1917, pp. 284–290.

It is suggested that, when the material is originally magnetized, energy is stored in the material before movement takes place, as in any elastic body subjected to a mechanical pull. This storing of energy may be due to static inertia, elasticity or, perhaps, to some other simple cause. When the current is removed this energy is released and is dissipated in changing the flux density. Energy absorbed due to friction will, of course, be dissipated in the form of heat.

It is quite likely that the energies may be measured by areas and that relationships exist, for example, between the areas, between curves *A* and *B* of Fig. 1, which represents the energy absorbed in magnetization which does not produce an additional flux change, and area *O–K–E–O*, Fig. 2, which represents the energy released by the breaking of the current, which energy produces a flux change.

TESTS. SERIES I.

A number of tests were made to determine point *E*, Fig. 2. This point represents a negative current value the release of which permits the flux value to return to zero.

The proof of zero flux consisted of the simple test of reapplying the current to give the maximum flux density desired and then reversing the direction of the current and, in both instances, noting the flux change. When repeated trials showed the flux change on reversal to be twice that obtained on applying the current, we know that the original flux value was zero.

After the point *E* was obtained, *B–H* curves were determined for test specimens of silicon steel and standard iron to various values of *B* maximum.

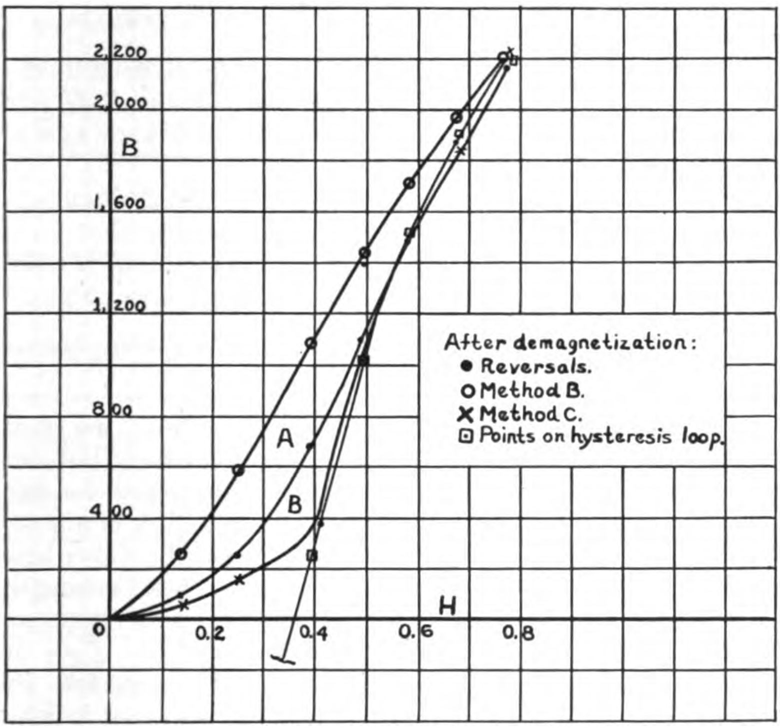
Tests were made after each of the three methods of demagnetization and in each case hysteresis loops were obtained for each maximum value of *H* and for each method of demagnetization.

The *B–H* tests were made by the well-known Roland ring method and the hysteresis loops by the step-by-step method. In every case the observations were repeated a number of times with the same increments of *H* and the final data taken as the average flux increment for each change of *H*. The maximum variation in any one test from the mean value taken was slight in every instance.

DISCUSSION OF TEST RESULTS.

Fig. 3 is typical, showing the nature of the *B–H* curves following the three methods of demagnetization previously described. These emphasize, as has already been pointed out, that great care must be taken properly to demagnetize magnetic material and in interpreting results. These curves again prove that the obtaining of a zero flux value in itself is

FIG. 3.



B–H curves of silicon steel to *B* max. 2,200. Area *A* ≎ 14.2 ergs. Area *B* ≎ 7.8 ergs.

not sufficient, as the material possesses different potentialities depending upon its previous magnetic history.

The reason that the three *B–H* curves are not alike is a matter of great interest and possible importance. It is evident that although at zero flux values the magnetic elements are in a state where the plus magnetisms and negative magnetisms neutralize each other, yet obviously this is

accomplished in a different manner for the three cases considered.

It is of especial interest to note that, when the flux density is already being changed in a certain direction (as regards positive and negative) or when the material is in a state of rest after having been changed in a certain direction, further flux changes in the same direction are accomplished, to a certain flux density at least, with less energy than if the flux change is in the opposite direction to that preceding its arrival to the zero flux density.

Taking the B–H curve obtained after demagnetization by reversals as the reference curve, we see that the B–H curve obtained after demagnetization by Method "B" shows greater flux values for the same H values.

It is obvious that the area between the two B–H curves is a measure of the difference of energy involved; that is, the energy in ergs per cm.[3] of material is equal to the B–H square between the curves, divided by 4π, i.e., ergs per cm.[3] $= \dfrac{\text{area in } B\text{–}H \text{ squares}}{4\pi}$. We will designate this area as Area "A."

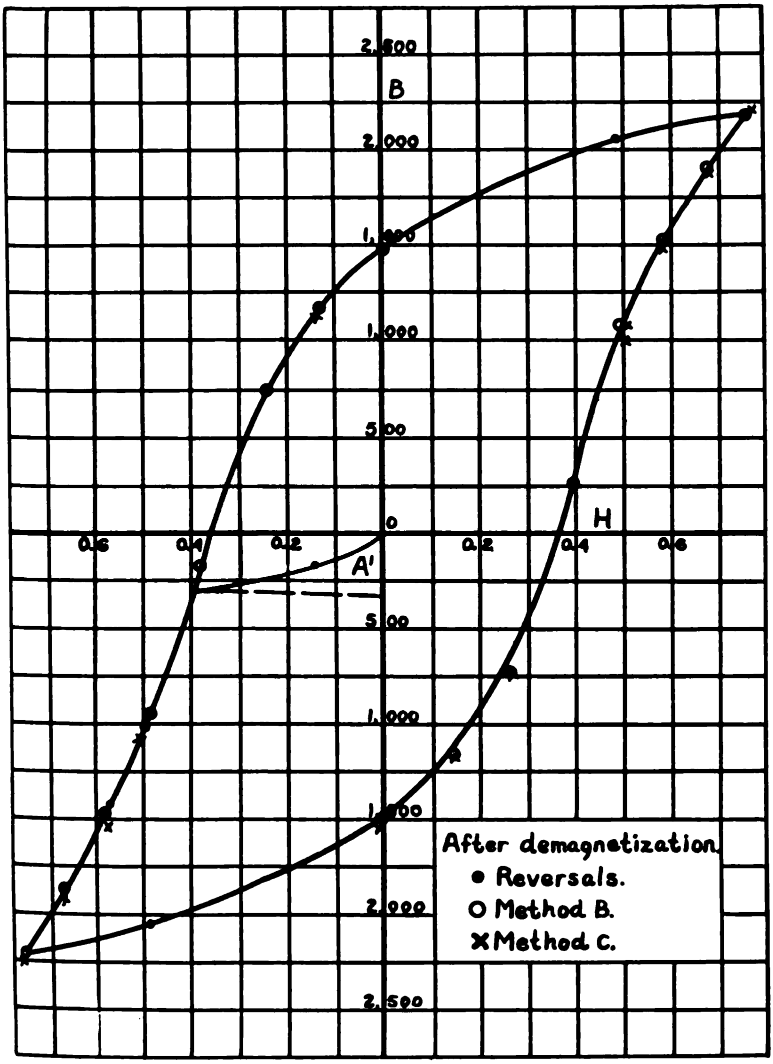
In the Bureau of Standards publication these two curves cross whereas in this investigation the curves meet but cross only in one instance. There seems to be no reason for these curves crossing unless, as may be a fact, the flux is not only more easily increased in the same direction, but also has a tendency to increase at the same rate at which it is changing.

Comparing the B–H curves obtained after demagnetization by Method "C" with the reference B–H curve, we find much lower flux values for the same H. Here we find that the flux change is in the opposite direction from that in which demagnetization was accomplished and consequently greater energy is required to obtain a given flux density, the additional amount of which may be found from the area between these two B–H curves, which we will designate as Area "B."

From the tests made, this third B–H curve seems the least easy to explain. It approaches the ascending quarter of the hysteresis loop very rapidly and in some cases goes beyond the loop, that is, for a given H the B value is less than the points on the loop. The points on this B–H curve in some instances

also recross the loop and again show points inside the loop as the induction is raised.

FIG. 4.



Hysteresis loops of silicon steel. *B* max. = 2,184. Loss = 203 ergs. Area *A'* ≈ 3.5 ergs.

Fig. 4 is a typical hysteresis loop which shows that if three loops were drawn to represent the points obtained after

the three methods of demagnetization there would not be a great difference in areas. The results obtained after demagnetization by Method "*C*" show greater differences than the differences obtained in the case of demagnetization by Methods "*A*" and "*B*."

Another area of interest is the area A' such as shown in Figs. 2 and 4. This area is a measure of the energy discharge after the removal of the current in demagnetizing by Methods "*B*" and "*C*." This area is not as great as the area involved for the same maximum flux densities in the cases of areas "*A*" and "*B*." A reason which may be assigned for this discrepancy is that some of the energy represented by areas "*A*" and "*B*" is discharged by raising flux values at the end of each step and the maximum flux density of the loop; also in going from the maximum flux density to the residual magnetism there is a discharge of energy from the material into the system and proceeding from the residual magnetism to point "*E*" there is a further absorption of energy. The area A' represents the true amount of energy stored in the material by virtue of the "magnetic elasticity" at the time the conditions in the material are as represented by point "*E*".

The energies involved as amounts and as percentages of the energies of the hysteresis loops are given in Table I.

TABLE I.

Energies Represented by Areas.

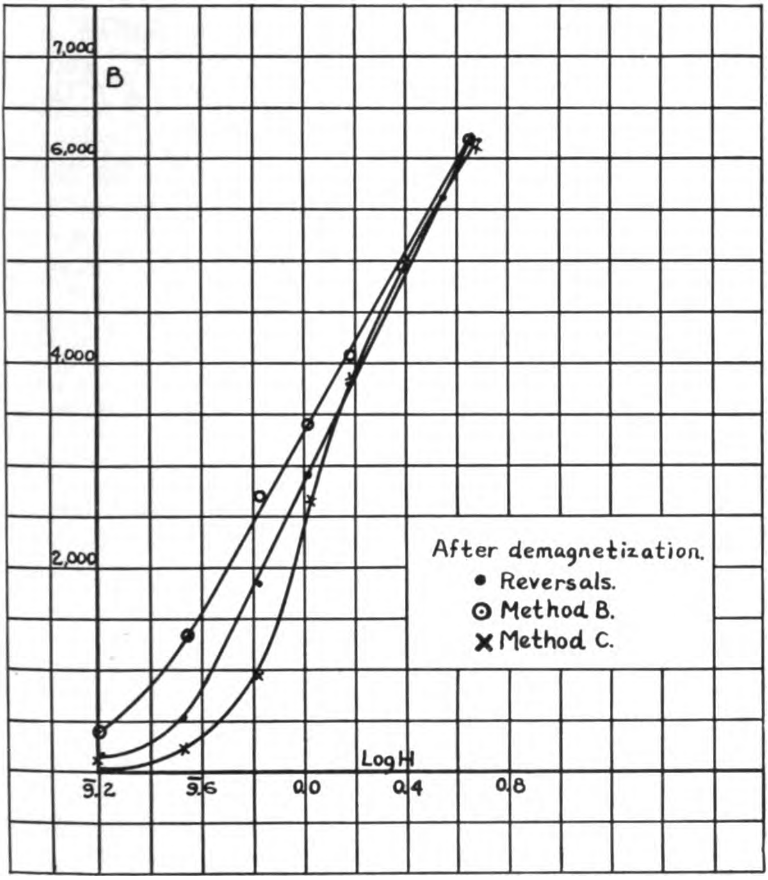
Steel.	*B* max.	Losses in Ergs.				*A* as % of Loop.	*B* as % of Loop.	*A'* as % of Loop.
		Loop.	*A*	*B*	*A'*			
si.......	6,190	1,143	87	65	13	7.6	5.7	1.1
si.......	3,702	482	41	14.5	5.3	8.5	3.0	1.1
si.......	2,184	203	14	4.8	3.5	6.9	2.4	1.7
std......	6,264	1,695	110	39		6.5	2.3	

EQUATION OF B-H CURVES.

In 1891 Dr. A. E. Kennelly showed that for magnetic materials the reluctivity (which is the reciprocal of the permeability), when plotted against the magnetizing force *H*,

gives a curve which from minimum reluctivity upwards approximates a straight line over a wide range of values.[8]

FIG. 5.



B–log *H* curves of silicon steel to *B* max. 6,260.

Equations for these curves have been published in previous papers.[9]

[8] "Magnetic Reluctance," A. E. Kennelly, *Trans. A. I. E. E.*, Vol. VIII, 1891, pp. 485–517.

[9] "Reluctivity of Silicon Steel," John D. Ball, *Gen. Elect. Review*, Vol. XVI, 1913, pp. 750–754.

"Investigation of Magnetic Laws for Steel and Other Materials," John D. Ball, JOUR. FRANKLIN INST., Vol. 181, 1916, pp. 459–504.

In the present investigation attempts were made to find if the results gave any rational equation. Curves were plotted showing the relationships between B–H, log B–log H, and log B–H. These gave no desirable results. However, the curves of B–log H proved to be more interesting, as the upper portions gave straight lines for the "A" and "B" methods of demagnetizing. A typical curve of B–log H is shown in Fig. 5.

The slopes of these curves were calculated and are given in Table II.

TABLE II.

Slopes of B–log H Curves.

Steel.	B max.	Slopes demag. A.	Slopes demag. B.
si	6,190	5,220	4,130
si	3,702	5,570	4,280
si	2,184	5,570	3,880
std	6,264	13,950	8,870

If the B–log H curve is a straight line and the slope proves to be constant for all materials, an equation may be formed in which the intercept would be a constant depending upon the material.

TESTS. SERIES II.

The second series of tests consisted of obtaining a number of hysteresis loops taken on the same two rings used in the first series.

The distinctive feature of these tests consisted of the fact that for each flux density selected loops were taken using an average of eighteen points in the step-by-step process and additional loops were taken using approximately a fifty per cent. additional number of points.

The object of the two groups of tests at the same inductions was to find if there were any differences in the losses indicated or if, at a given induction, more energy would be required as the number of steps involved became greater. On the theory of static inertia being a governing factor in determining the energy required to effect a flux change, or if the difference in losses due to starting and running friction, or similar phenomena, are appreciable, loops involving a greater number

of points or more stops and starts might show a greater area, which would indicate that there was more energy required.

The same method of testing was used as in the first series except that the precision of the galvanometer readings was improved by the substitution of microscopic lenses for the eye piece.

In the second series the rings were always demagnetized by Method "A," which is by reversals.

In every case the tests were repeated a number of times with the same increments of H and the final data taken as the average flux increment for each change of H. The maximum variation, in any one test, from the mean value was slight in every instance.

DISCUSSION OF TEST RESULTS.

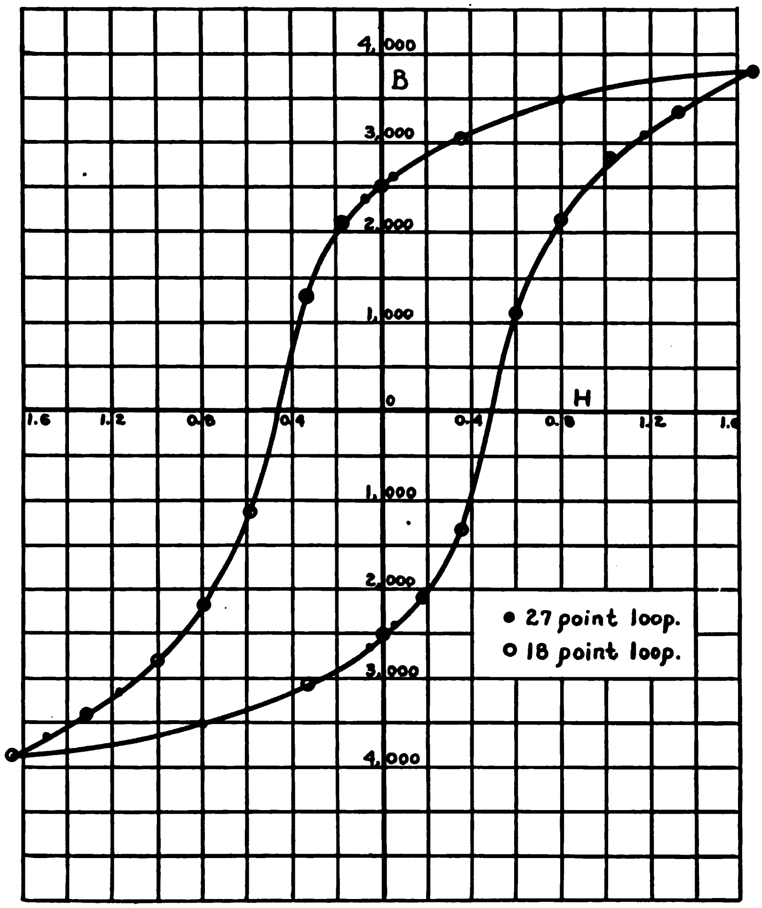
A typical loop indicating the results obtained is shown on Fig. 6. Taking the value of B maximum of each pair of loops as that of the loop taken with the greater number of points as the reference value, we find slight discrepancies between them and the loops with the smaller number of points. Also, in some cases, there are differences between the maximum values in cases of each half of the same loop. These differences are small and would not affect the conclusion reached from these tests.

Examination of all the loops obtained showed that it would be difficult to prove that the hysteresis losses of loops with the greater number of points are greater than the loops with the smaller number. While some individual points indicate this to be true, there are other points which indicate the opposite, and in all cases, when the errors of observation are considered, the differences are not sufficient to warrant conclusions.

The difference between the number of points taken for each loop is small and there are obvious reasons why this part of the investigation cannot be extended to any great extent. If fewer points were taken, it would be difficult properly to determine the true shape of the loop; in fact the areas would depend somewhat upon the shape of the curve rule in the possession of the investigator. Additional points involve cumulative errors and these affect results, depending not only on their direction and amount but also on the part of the curve where the points in question occur.

A more fruitful analysis proved to be the comparing of the maximum flux densities which were reached with a given

FIG. 6.



Hysteresis loops of silicon steel. *B* max. = 3,824. Loss = 526 ergs.

maximum *H* value in cases where the loop was taken point by point and in cases where the *H* values were reversed or where a half loop is taken in a single step. This comparison is shown in Table III, which includes test results from both Series I and Series II.

TABLE III.

Comparison of Maximum Points.

SERIES I.

Steel.	Avg. Density Hyst.	Avg. Density Reversals.	Hyst. Density Dif. from Reversals.
si.........	6,190	6,260	− 70
si.........	3,702	3,763	− 61
si.........	2,184	2,200	− 16
std......	6,264	6,290	− 26

SERIES II.

si.........	1,368	1,378	− 10
si.........	2,540	2,568	− 28
si.........	3,806	3,838	− 32
si.........	5,173	5,188	− 15
std.......	1,471	1,479	− 08
std.......	2,623	2,645	− 22
std.......	9,054	9,000	+ 54

In all but one case the B maximum obtained by reversals exceeded those obtained by reaching them by the steps of the loops.

Tests were made to determine the amount of errors, if any, which might be due to "magnetic creepage." These tests showed that no such errors are involved in the present investigation.

A series of tests were made which showed that the self-damping of the galvanometer need not be considered as affecting the results obtained.

ACKNOWLEDGMENTS.

The investigation, of which this paper is an abstract of the results obtained, was conducted in the Physics Department of Marquette University at Milwaukee, Wisconsin, and was submitted to that institution as partial requirements for the Degree of Doctor of Philosophy. The work was done under the direction of Dr. Charles H. Skinner, whose guidance, interest and encouragement were more than inspirational.

The results obtained were made available through the tests performed by Mr. Simon Share, a student in the College

of Liberal Arts at Marquette University. His untiring efforts and patience cannot be acknowledged too highly.

The furnishing of the test specimens was one of the many courtesies received by the author from Mr. James R. Craighead, late of the General Electric Company.

SUMMARY.

In this investigation the first series of tests consisted of obtaining zero flux in two varieties of steel from various maximum flux values and by three different methods. *B–H* curves were obtained after demagnetization by the three methods and from the maximum value of these *B–H* curves hysteresis loops were taken.

One method of demagnetizing was that suggested by the U. S. Bureau of Standards, which consists of current reversals through a magnetizing winding, in which current values are gradually reduced to zero. The second method consisted of applying a negative current of such an amount that the resultant value of flux would be such that when the current was released the flux value would go to zero. The third method was substantially the same as the second except the zero flux was approached from the direction of opposite polarity.

The resultant *B–H* curves proved to be different from each other and to depend upon not only their origin but the previous history of the material as regards methods of demagnetization.

The areas between the curves were evaluated.

It was found that in cases of two of the three typical *B–H* curves the *B*–log *H* curves gave straight lines for part of the range involved.

A second series of tests consisted of taking a set of hysteresis loops and repeating the determinations, using a greater number of steps to find if by taking a greater number of steps there might be a greater indicated energy loss. The results of this group of tests were not sufficiently definite to warrant conclusions.

MILWAUKEE, WISCONSIN,
May 14, 1928.

ARMATURE REACTION IN MULTIPOLAR DIRECT CURRENT DYNAMOS.

BY

ALBERT P. STROM, M.S., E.E.

Instructor, School of Electrical Engineering, Purdue University.

It is generally understood that armature reaction affects the flux entering the armature and plays an important part in determining the operating characteristics of dynamos. It is therefore a subject of considerable interest to those engaged in the design or operation of electrical machinery.

Any conductor carrying electric current sets up a magnetomotive force in every path linking the conductor. The conductors on the armature of a dynamo are therefore sources of magnetomotive force (m.m.f.) whenever current flows in them. Under no-load conditions, the field windings are the only sources of m.m.f. in the magnetic circuits of a dynamo, but it is apparent that when the machine is loaded the armature also produces an m.m.f. The magnetic flux entering the armature from the field poles, is therefore due to the combined m.m.f.s of the field windings and of the armature windings. The magnetic effect of the armature is generally known as armature m.m.f. or armature reaction.

Various explanations, usually of a rather qualitative and superficial nature, applying to the special case of a two-pole dynamo, are to be found in numerous sources, but a simple quantitative explanation based wholly on fundamental principles is not common. It is the purpose of this article to derive from the fundamental principles involved, a reasonable explanation of armature reaction equally applicable to multipolar and bipolar machines.

The greatest difficulty in obtaining a clear understanding of problems in which magnetic circuits are involved, is probably due to an almost universal misconception of the nature of the common unit of m.m.f. the "ampere turn." This name is in itself somewhat misleading and it might well be called "ampere conductor" instead, as we shall see later.

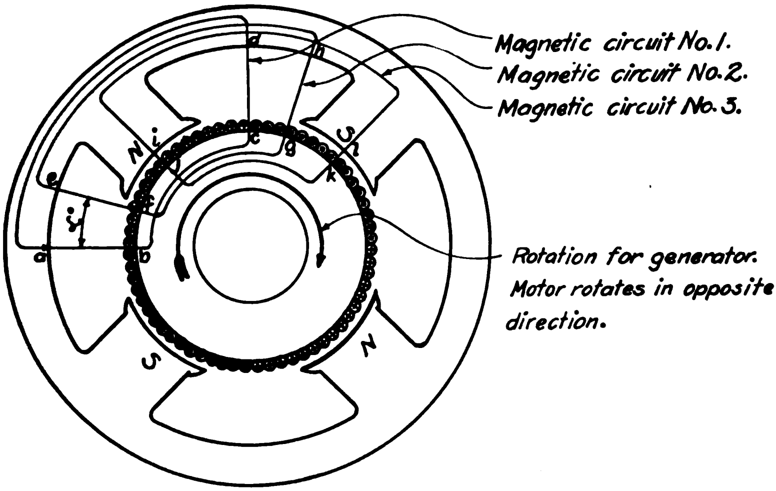
There is, probably due to this name, the common though incorrect conception that an ampere turn is a complete loop of wire carrying one ampere, inferring that the return conductor must be coiled and in close proximity to the outgoing wire. It is this last inference that is wrong, for the location or form of the return conductor does not change the magnitude of the m.m.f. that the electric circuit supplies to any magnetic circuit linking it. *A conductor carrying a current of one ampere exerts a m.m.f. of one ampere turn on any and every closed path linking it, regardless of whether the return wire be near or far from it.* For example, a transmission line wire carrying one ampere exerts a m.m.f. of one ampere turn on any path surrounding it. Suppose, that an iron rod were bent in the form of a ring about the wire. The flux induced in this iron ring by the straight transmission line wire would be the same as if a small turn of wire carrying one ampere were wrapped closely about the ring. Furthermore, the path chosen about the transmission line wire need not be of iron. It may be a path in the air normally surrounding the conductor. Regardless of the material or the shape of the path, and regardless of whether the return conductor hugs the outside surface of the path or returns miles distant, *if a conductor carrying one ampere links a magnetic circuit it exerts in this circuit a magnetomotive force of one ampere turn.* If N conductors link the magnetic path, each carrying I amperes, the m.m.f. on the path (and on every other path linking the conductors) is N times I ampere-turns or $0.4\pi NI$ gilberts.

Whenever current flows in the armature conductors of a dynamo, these conductors are therefore sources of m.m.f. in all magnetic paths linking the conductors. The flux in the magnetic circuits of the machine is therefore the result of the combined magnetomotive forces of field and armature windings.

The effect of the current in the armature conductors can best be shown by considering a particular case, and applying to it the fundamental principles above outlined. Figure 1 shows a four-pole dynamo with brushes set on the no-load neutral, i.e., in such a manner that current in the armature conductors reverses midway between each pair of poles. On the armature, from the center line midway between one pair

of poles to the center line between the next pair, there is therefore a group of conductors in all of which current flows in the same direction, and in which the value of the current is I_c, the armature current per path.

FIG. 1.



Armature reaction with brushes set at geometric neutral.

Excepting for high saturation in the iron portions of the magnetic circuit, the yoke and pole may be considered as one magnetic equipotential surface. It is not necessary to make this assumption, but in order to keep this explanation as simple as possible, it will be made in this discussion.

Consider now, the closed magnetic circuit No. 1, in Fig. 1. This is so drawn that the air portions of the path, a–b, and c–d, are exactly one pole pitch apart, and hence are symmetrically located. All conductors enclosed in this path carry current in a + direction. The total armature m.m.f. in the closed circuit a, b, c, d, due to the conductors linked with it, is therefore NI_c, where N is the number of conductors per pole pitch and I_c the current per conductor. Since, on the assumption of zero reluctance of the iron circuit, the two air paths a–b, and c–d, consume all this m.m.f. and since they are symmetrically chosen, the m.m.f. on a–b equals m.m.f. on path c–$d = \dfrac{NI_c}{2}$.

Circuit No. 1 has purposely been chosen at the geometric neutral. It is seen that in this circuit, all the armature conductors linking it, carry positive current and that therefore, the armature m.m.f. that acts on path *a–b* of this circuit is equal to $\frac{\text{conductors per pole pitch} \times I_c}{2}$, which is the maximum possible armature m.m.f. on any portion of the air gap. This maximum value of m.m.f. is commonly known as the armature m.m.f. per pole.

Consider now any other closed magnetic circuit, as circuit No. 2. This circuit has also been chosen so that its air gap portions are symmetrically located one pole pitch apart. The total m.m.f. supplied by the conductors linked is then consumed in the air gaps *e–f* and *g–h*, one half of the m.m.f. being consumed in each gap. Referring to the figure, it is seen that for this path, not all of the conductors linked carry current in a positive direction. There are three conductors carrying negative current, and these neutralize the m.m.f. of three other positive conductors.

The m.m.f. in circuit No. 2 is therefore the m.m.f. of all positive current-carrying conductors minus the m.m.f. of all negative current-carrying conductors enclosed in the path. In this case, since there are 16 conductors enclosed, three of which carry negative current, the net ampere turns in circuit No. 2 is $13I_c - 3I_c = 10I_c$. The m.m.f. on path *e–f* is therefore half this value or $5I_c$ ampere turns.

This argument can readily be generalized, and put into mathematical form, where

N = conductors per pole,
I_c = current per conductor,
α = displacement in electrical degrees of path No. 2 from the geometric neutral.

Since there are 180 electrical degrees per pole pitch, the number of conductors carrying negative current is

$$\frac{\alpha}{180} N.$$

The net effective conductors carrying positive current are then

$$N - \frac{2\alpha}{180} N$$

and the net effective ampere turns in the closed circuit are

$$I_c\left(N - \frac{2\alpha}{180} N\right).$$

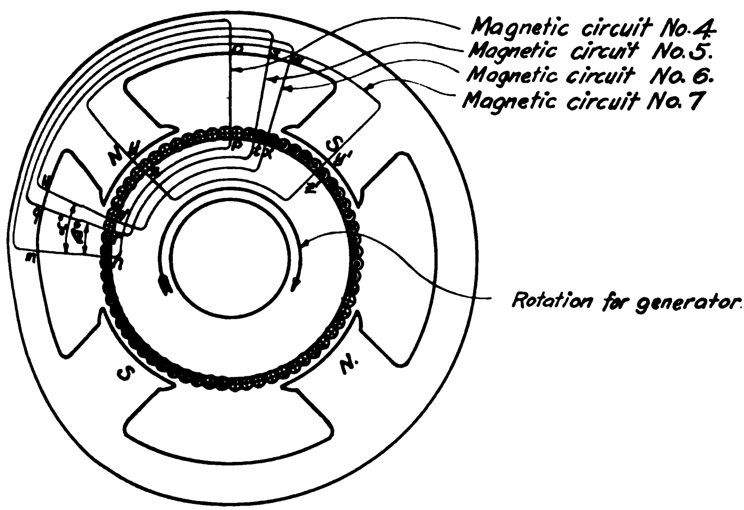
The ampere turns on the path e–f is one-half of this value, or, armature ampere turns at e–f equals $\frac{NI_c}{2}\left(1 - \frac{2\alpha}{180}\right)$. . . . . (1).

It is to be noted that the armature m.m.f. as given above is a linear function of α. It has a maximum value of $\frac{NI_c}{2}$ at geometric neutral, and zero value where $\alpha = 90°$, i.e., directly upon the center of the pole.

EFFECT OF SHIFTING BRUSHES.

If, as in Fig. 2, the brushes are shifted in the direction of rotation, by an angle β, the position of reversal of current in

FIG. 2.



Armature reaction with brushes shifted $\beta°$ off geometric neutral.

the armature conductors shifts forward with the brushes. The maximum armature m.m.f. will now be exerted in the

path linking conductors, all of which carry + current, i.e., the circuit including the two air paths immediately above the brushes. The m.m.f. in this path is exactly the same as the m.m.f. at the geometric neutral path before the brushes were shifted. It may be noted further that the armature m.m.f. in any path is now exactly the same as for a similar path in Fig. 1, situated β degrees farther back.

This effect may also be expressed mathematically. In the following discussion, let

α = angular displacement of the magnetic path under consideration, from geometric neutral,
β = angular brush shift ahead (in direction of rotation), from geometric neutral,
I_c = current per conductor,
N = number of conductors per pole,
$Y = (\beta - \alpha)$.

The maximum armature m.m.f. occurs where α equals β, at which point all conductors linking the circuit carry current of the same sign. The m.m.f. of the whole circuit at this point is therefore NI_c, or, for one side (g–h) of the path, ampere turns equal $\frac{NI_c}{2}$.

In a path Y degrees from the point on the armature at which the current in the armature conductors reverses (see Fig. 2), the conductors carrying negative current are $\frac{Y}{180}N$. These neutralize an equal number of positive current-carrying conductors leaving $\left(N - \frac{2Y}{180}N\right)$ effective conductors.

But Y is the numerical difference of β and α irrespective of sign; it is always a positive quantity. This may readily be seen by referring to Fig. 2. The effective ampere turns in the closed path are therefore

$$\left(N - \frac{2(\alpha - \beta)}{180}N\right)I_c \text{ for } \alpha > \beta$$

or

$$\left(N - \frac{2(\beta - \alpha)}{180}N\right)I_c \text{ for } \beta > \alpha.$$

The armature m.m.f. per air gap (path g–h, Fig. 2) is therefore

$$\frac{NI_c}{2}\left(1 - \frac{2(\alpha - \beta)}{180}\right) \text{for } \alpha > \beta \ldots\ldots\ldots\ldots (2)$$

and

$$\frac{NI_c}{2}\left(1 - \frac{2(\beta - \alpha)}{180}\right) \text{for } \beta > \alpha \ldots\ldots\ldots\ldots (2a)$$

The ampere turns at the geometric neutral are now those given by the above equation where α equals 0, or

$$\frac{NI_c}{2}\left[1 - \frac{2\beta}{180}\right] \ldots\ldots \qquad (3)$$

This quantity is in general known as the cross magnetizing component of armature ampere turns. It is the total m.m.f. tending to produce flux at the geometric neutral position of the machine, since the net pole m.m.f. at this point is zero.

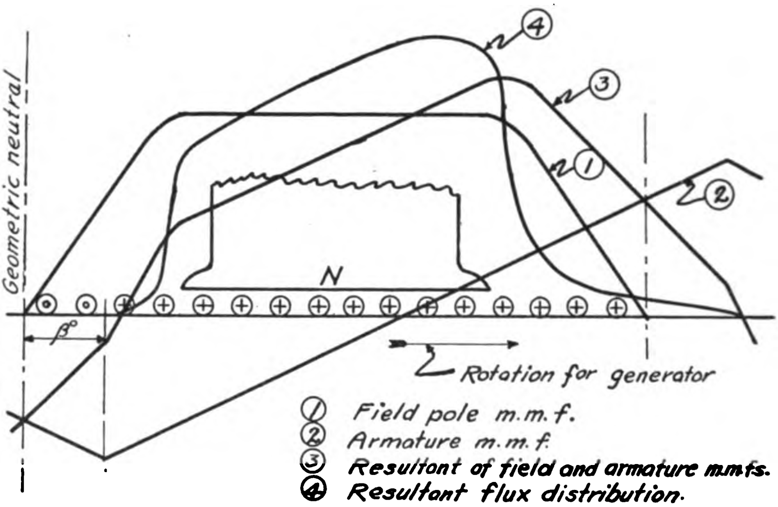
Since the m.m.f. as shown by the equation (2) is a linear function of α (β being a constant), the average m.m.f. over the pole face due to the armature is the value at the center of the pole. For brushes set on geometric neutral, the armature m.m.f. at the center of the pole is seen to be zero. Where brushes are shifted by an angle β, the m.m.f. at the center of the pole is

$$\frac{NI_c}{2}\left[1 - \frac{2(90 - \beta)}{180}\right] = \frac{NI_c}{2}\left(\frac{2\beta}{180}\right) = NI_c\left(\frac{\beta}{180}\right) \ldots\ldots (4)$$

This is the average m.m.f. over the pole face due to armature current. Since with brushes shifted in the normal direction (forward in a generator or backward in a motor), this part of the armature m.m.f. is opposed to the field m.m.f. It is commonly known as the demagnetizing component. It may be noted that equation (2) is the general form of equation (1), the latter being the special case in which the brush shift angle β is zero. Equations (3) and (4) are also special cases of equation (2), equation (3) being the case when the displacement angle, α, from geometric neutral is zero, and equation (4) the case when α is 90 degrees.

The armature m.m.f. for a particular case such as represented in Fig. 2 may now be plotted for each point on the armature surface. This results in a triangular form such as shown in curve No. 2, Fig. 3, with maxima above the points on the armature where current reverses.

FIG. 3.



Magnetomotive force and flux curves with brushes shifted $\beta°$ off geometric neutral.

The total m.m.f. effective to send flux into the armature is now the resultant m.m.f. of the windings on the pole, and the armature. The m.m.f. of the pole can readily be calculated, its maximum value being the product of the turns per pole and the field current. It is practically constant under the pole face, and decreases rapidly in almost linear form from the edges of the pole to the geometric neutral, as shown in curve 1, Fig. 3. The m.m.f. of the pole is less than its maximum value on some of the flux paths beyond the pole tips, because the flux that enters the armature at these points, does not link all of the field windings. That is, the flux emerges from the pole at some point above the lower edge of the field coil. The resultant of curves 1 and 2 is the m.m.f. setting up flux in the magnetic circuit (curve No. 3).

The flux density at any point on the armature may now readily be calculated if the average reluctance of the path

from the pole and yoke structure to the armature be known. For this calculation, consider a flux path terminating on one sq. cm. of the armature surface. In the air gap under the pole, the path of flux is easily and accurately estimated. In the interpolar space, the determination of this flux distribution is not so simple, but a fair approximation may be made by cut and try methods. Details of such methods may be found in various books on generator design. Having determined the flux distribution, it is then a fairly simple matter to calculate the reluctance of a flux tube ending on one sq. cm. of the armature surface. The density at this point on the armature is then equal to the m.m.f. as shown on curve 3, divided by the reluctance of the flux tube. In this manner a resultant flux distribution curve as shown by curve No. 4, Fig. 3, may be drawn.

This curve is of particular importance since it shows the final effect of the armature m.m.f. in distorting the flux distribution, and consequently indicates the distortion of the generated voltage in the coils of the machine.

A Calorimeter for the Determination of the Heat Developed by Fruit. EZER GRIFFITHS. (*Proc., Phys. Soc.*, London, Feb. 15, 1928.) To the plant physiologist a knowledge of the rate of production of heat by apples is of value for the light it throws on the oxidation of sugar and malic acid and the formation of carbon dioxide, while to the refrigerating engineer it furnishes data of use in caring for cargoes of apples.

The measurements were conducted in a small room maintained at a constant temperature. In this was a metallic box well insulated with granulated cork. Two identical containers were within the box; one held apples, the other dummy apples of spheres of thin glass filled with wet glass wool to provide the same heat capacity as the real apples in the first receptacle possessed. Into each container projected four tubes each of which held 10 yards of nickel wire. This wire formed a resistance thermometer, the 40 yards in each enclosure being joined in series. The total wire in each container was joined to an arm of a slide wire bridge so arranged that a shifting of the contact by one cm. along the wire indicated a difference of temperature between the enclosures of .003° C. A current of air flowed for long periods through the aggregate of apples. By regulating its speed it was possible to keep them in atmospheres containing from 2 to 10 per cent. of CO_2. Since water was evaporated by the air current, its gain in humidity had to be determined and the heat of vaporization allowed for.

The rise in temperature observed was of the order of magnitude of .15° C. Unsound apples developed about 50 per cent. more heat than sound ones. The content of CO_2 in the atmosphere surrounding the apples scarcely affected the heat development at all. The energy removed by the air current represented from 1/3 to 4 per cent. of the total heat developed by the fruit.

"From the preliminary observations recorded in this paper, it may be assumed that a cubic foot container of apples at a temperature of 20° C. generates heat at the rate of 0.14 calorie per second." On this basis 100,000 bushel cases of apples would evolve heat at the rate of 132 H.P. The heat conducted inward through the sides of the vessel is about three times as great as that produced by the apples.

G. F. S.

MEDAL DAY MEETING.

The annual Medal Day meeting of The Franklin Institute was held in the Hall of the Institute on the 16th of May. It was also the stated monthly meeting for May, and was called to order by the acting president, the senior vice-president, Mr. Henry Howson.

The acting president announced that the minutes of the last meeting had been printed in the May number of the JOURNAL and that, if there were no objection, the minutes would be approved as printed. As no objection was offered, the minutes were declared approved.

The acting president called upon the secretary, Dr. Howard McClenahan, who announced the donation to the Institute of a portrait of Mr. William Sellers, a former president and long time member of the Board of Managers of The Franklin Institute. The portrait had been especially painted for the Institute and was presented by the son of Mr. Sellers, Alexander Sellers, Esq., of Philadelphia. The Secretary made expression of the sincere appreciation of the Institute for this greatly valued portrait.

The Chairman of the meeting then announced that the presentation of medals was the next order of business, and stated that all of the medals which had been awarded during the present Institute year, upon the recommendation of the Committee on Science and the Arts, would be presented at this time.

AWARD OF LONGSTRETH MEDALS.

To Dr. Frank N. Speller, National Tube Company.

The Chair recognized Mr. G. H. Clamer, sponsor for Dr. Speller. Mr. Clamer said: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Dr. Frank N. Speller of the National Tube Company, as the recipient of the Edward Longstreth Medal, in consideration of his invention of a method of manufacturing scale-free pipe and its successful application."

The Chairman presented the medal, certificate and report in the following terms: "Dr. Speller, by virtue of the authority conferred upon me by The Franklin Institute of the State of Pennsylvania, I have much pleasure in presenting to you, upon recommendation of the Committee on Science and the Arts, and with the unanimous approval of the Board of Managers of the Institute, an Edward Longstreth Medal. I congratulate you upon this deserved recognition."

In acknowledging the award, Dr. Speller said: "I wish to express my thanks for the honor you have done us and assure you it is much appreciated."

To Mr. Warren P. Valentine, Philadelphia, Pa.

The Chair recognized Dr. G. S. Crampton, sponsor for Mr. Valentine, who said: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Warren P. Valentine, as the recipient of an Edward Longstreth Medal, in consideration of the meritorious work shown in the improvement of the mechanical and optical part of the Abbe Refractometer, thereby increasing its accuracy."

In making the presentation of the medal and certificate the acting president said: "Mr. Valentine, I have much pleasure in presenting to you, in the name of The Franklin Institute of the State of Pennsylvania, upon recommendation of its Committee on Science and the Arts, and with the unanimous approval of its Board of Managers, the Longstreth Medal and Certificate. I congratulate you upon the masterly workmanship upon which this award is based."

In acknowledgement of the award Mr. Valentine said: "Mr. Chairman and Members of the Board, I wish to express my appreciation and thanks for this award."

AWARD OF WETHERILL MEDALS.

To Mr. Albert S. Howell, The Bell-Howell Company.

The Chair recognized Mr. W. N. Jennings as sponsor for Mr. Howell.

Mr. Jennings: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Albert

S. Howell, of the Bell-Howell Company, as the recipient of the John Price Wetherill Medal, in consideration of the ingenuity shown in successfully embodying the principles of the professional moving picture camera and projector in instruments especially adapted to the use of the amateur and for the excellence of construction of these instruments."

The Chairman spoke as follows: "Mr. Howell, I am very glad to present to you, on behalf of The Franklin Institute and upon the recommendation of its Committee on Science and the Arts, and with the hearty approval of its Board of Managers, the John Price Wetherill Medal and Certificate. We are gratified to have you added to the honor roll of The Franklin Institute."

Mr. Howell said, "Thank you."

To Dr. Frank E. Ross, Yerkes Observatory, University of Chicago.

The Chair recognized Prof. W. R. Wright as sponsor for Dr. Ross.

Professor Wright: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Dr. Frank E. Ross, of the Yerkes Observatory, in absentia, as the recipient of a John Price Wetherill Medal, in consideration of his marked contributions to Astronomy in the design of wide angle astrographic lenses of exceptional speed and definition."

The Chairman then presented the medal and certificate to the Secretary of the Institute: "Mr. Secretary, by authority vested in me, I confer upon Dr. Frank E. Ross, by action of the Board of Managers, a John Price Wetherill Medal and Certificate. I request that you transmit them to Dr. Ross with our congratulations."

The medal and certificates were received by the Secretary for transmission to Dr. Ross.

AWARD OF LEVY MEDAL.

To Professor Vannevar Bush, Massachusetts Institute of Technology.

The Chair recognized Professor H. J. Creighton, sponsor for Professor Bush.

Professor Creighton: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Professor Vannevar Bush of the Massachusetts Institute of Technology, as the recipient of the Louis Edward Levy Medal, with special reference to his fellow workers, Messrs. G. F. Gage, H. L. Hazen, H. R. Stewart, for two papers, 'A Continuous Integraph' and 'Integraph Solution of Differential Equations' which appear in the JOURNAL OF THE FRANKLIN INSTITUTE for the year 1927."

The Chairman presented the award in the following terms: "Professor Bush, I have much pleasure in conferring upon you the Louis Edward Levy Medal and Certificate, with congratulations to you for the high quality of the articles upon which this award is based, and with special mention of your three co-workers, Messrs. Gage, Hazen and Stewart."

Professor Bush replied: "I am highly appreciative of the honor which is conferred upon me by The Franklin Institute, and I am sure I can also convey to you the appreciation of my fellow-workers."

AWARD OF HENDERSON MEDAL.

To Mr. William F. Kiesel, Jr., the Pennsylvania Railroad.

The Chair recognized Mr. G. H. Benzon, Jr., sponsor for Mr. Kiesel.

Mr. Benzon: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. William F. Kiesel, Jr., of the Pennsylvania Railroad, as the recipient of the George R. Henderson Medal, in consideration of his numerous inventions of outstanding value in locomotive and railway car design and construction."

The Chairman in presenting the medal and certificate said: "Mr. Kiesel, The Franklin Institute is happy to confer upon you, upon the recommendation of its Committee on Science and the Arts, the George R. Henderson Medal and Certificate, and to congratulate you upon your many and valuable contributions to Railway Engineering and Equipment."

Mr. Kiesel responded: "I appreciate the honor conferred upon me by you on behalf of The Franklin Institute."

AWARD OF CLARK MEDAL.

To Arthur Graham Glasgow, Esq., Humphreys and Glasgow, Ltd., London, England.

The Chair recognized Mr. F. R. Wadleigh, sponsor for Mr. Glasgow.

Mr. Wadleigh: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Arthur Graham Glasgow, of London, England, as the recipient of the Walton Clark Medal, in consideration of his outstanding and valuable work in the technology and development of the manufactured gas industry."

In presenting the Medal and Certificate the Chairman said: "Mr. Glasgow, by virtue of authority vested in me, I confer upon you, in the name of The Franklin Institute of the State of Pennsylvania, the Walton Clark Medal and Certificate. I congratulate you upon your many contributions of value to the gas industry, and at the same time wish to express our appreciation to you for your trip from London, England, to receive this medal."

Mr. Glasgow in accepting the award, said: "It is to me intensely gratifying to receive the Walton Clark Medal, as the second recipient of it from this ancient and eminent institution. I thank you."

AWARD OF POTTS MEDALS.

To Dr. Eugene E. Sullivan, in absentia, and Mr. William E. Taylor, of the Corning Glass Works.

The Chair recognized Mr. C. A. Hall, sponsor for Messrs. Sullivan and Taylor.

Mr. Hall: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Dr. Eugene C. Sullivan and Mr. William E. Taylor, of the Corning Glass Works, as joint recipients of a Howard N. Potts Medal, in consideration of the noteworthy contribution to the art of glass manufacture resulting in what is known as pyrex, a glass that has desirable qualities both for domestic and scientific purposes."

The Chairman presented the medal and certificate to Mr. Taylor: "Mr. Taylor, I have the honor to confer upon Dr.

Sullivan, in absentia, and you, jointly, the Howard N. Potts Medal and Certificate. I ask you to convey our congratulations to Dr. Sullivan upon his return from Europe, at the same time that you receive a full measure for yourself."

Mr. Taylor said: "I greatly appreciate this honor which you have conferred upon Dr. Sullivan and upon me, and I desire to thank you."

To Mr. Oscar G. Thurlow, the Alabama Power Company.

The Chair recognized Mr. F. H. Rogers, sponsor for Mr. Thurlow.

Mr. Rogers: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Oscar G. Thurlow of the Alabama Power Company, as the recipient of the Howard N. Potts Medal, in consideration of the novelty and ingenuity of its design, the careful investigation of the various elements affecting such design, its usefulness in increasing the potential output of hydroelectric plants under certain conditions and the successful application of his Backwater Suppressor."

The Chairman presented the medal and certificate to Mr. Thurlow and said: "Mr. Thurlow, we are happy to confer upon you the Howard N. Potts Medal and Certificate and to express our admiration for the ingenuity and sound knowledge embodied in your invention."

In expressing his appreciation Mr. Thurlow said: "I deeply appreciate this honor and not only for myself, but for my co-workers."

AWARD OF CRESSON MEDALS.

To Professor Vladimir Karapetoff, Cornell University.

The Chair recognized Mr. C. W. Bates, sponsor for Professor Karapetoff.

Mr. Bates: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Professor Vladimir Karapetoff, as the recipient of the Elliott Cresson Medal, in consideration of the ingenuity, inventive ability, skill in design and detailed theoretical knowledge of kinematics and

electrical engineering displayed in the development of his kinematic computing devices."

The Chairman presented the medal and certificate as follows: "Professor Karapetoff, by virtue of the authority conferred upon me by The Franklin Institute of the State of Pennsylvania, I have much pleasure in presenting to you, upon the recommendation of the Committee on Science and the Arts and with the unanimous approval of the Board of Managers of the Institute, the Elliott Cresson Medal and Certificate. As a student of physical science, I am grateful to you for your successful efforts to lighten the burden of electrical calculations."

Professor Karapetoff replied: "I deeply appreciate the honor and I take this opportunity to thank those who financed the project and made it possible."

To Mr. G. W. Elmen, Bell Telephone Laboratories, Inc.

The Chair recognized Mr. C. A. Hall, sponsor for Mr. Elmen.

Mr. Hall: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Gustaf W. Elmen of the Bell Telephone Laboratories, Inc., as the recipient of the Elliott Cresson Medal, in consideration of his extended researches in the magnetic characteristics of nickel-iron alloys resulting in the invention of permalloy, an alloy having high permeability and low hysteresis loss, and of its successful uses for the loading of submarine telegraph cables to secure high speed transmission, for the cores of loading coils and audio frequency transformers."

The Chairman presented the medal and certificate to Mr. Elmen in the following terms: "Mr. Elmen, The Franklin Institute is delighted to confer upon you the Elliott Cresson Medal and Certificate and to add you to our honor list because of your important discovery of permalloy."

Mr. Elmen responded: "I wish to express my deep appreciation of the honor conferred upon me."

To Mr. C. L. Lawrance, Wright Aeronautical Corporation.

The Chair recognized Mr. W. L. Brown, 3d, sponsor for Mr. Lawrance.

Mr. Brown: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Charles L. Lawrance of the Wright Aeronautical Corporation, as the recipient of the Elliott Cresson Medal, in consideration of his pioneer work in the development of the air cooled airplane engine, of his skill in bringing this engine to a high degree of perfection, and of his ability in carrying out its manufacture."

The Chairman then presented the medal and certificate: "Mr. Lawrance, I have great pleasure in conferring upon you the Elliott Cresson Medal and Certificate, and to congratulate you heartily upon the epochal development of the air cooled airplane engine for which you are responsible."

Mr. Lawrance said: "I want to thank you and the members of the Institute for this honor, and I want to thank you also on behalf of my co-workers in the Wright Aeronautical Corporation, who greatly helped to make the engine what it is today."

To Mr. Henry Ford, Ford Motor Company.

The Chair recognized Mr. Benjamin Franklin, sponsor for Mr. Ford.

Mr. Franklin: "Mr. Chairman, I have the honor to present to you, upon recommendation of the Committee on Science and the Arts of The Franklin Institute, Mr. Henry Ford of Detroit, Michigan, as the recipient of the Elliott Cresson Medal, in consideration of his rare inventive ability and power of organization by means of which he was able to effect high speed production of automobiles, revolutionizing the industry; and his outstanding executive powers and industrial leadership."

The presentation of the medal and certificate was made by the Chairman as follows: "Mr. Ford, in the name of The Franklin Institute, I am delighted to present to you the Elliott Cresson Medal and Certificate for your revolutionary contributions to the automobile industry. Few men have had the privilege of altering radically and happily the life of the world which you have known. We congratulate you sincerely."

In acknowledging the award, Mr. Ford said: "I am highly honored and thank you very sincerely."

AWARD OF FRANKLIN MEDALS.

To Professor Doctor Walther Nernst, University of Berlin.

The Chair recognized Dr. James Barnes, sponsor for the Franklin Medalists of the day.

Dr. Barnes: "Mr. Chairman, the Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts was unanimously of the opinion that a Franklin Medal be awarded to Doctor Walther Nernst, Professor of Physical Chemistry in the University of Berlin and Director of Technical Physics at the Reichsanstalt 'in recognition of his numerous and valuable contributions in physical and theoretical chemistry and particularly for his applications of the exact methods of thermodynamics to electro- and thermo-chemistry.'

"Doctor Nernst was born in 1864. After studying and teaching at Würzburg, Leipzig and Göttingen he was appointed in 1905 to the most distinguished chair of physical chemistry in the German Republic, that at the University of Berlin. In 1920 he received the Nobel Prize and in 1921 he was Rector of the University of Berlin.

"Professor Nernst is without a peer in the field of physical chemistry. Even to list his fundamentally important researches and discoveries would be a long task. I cannot however refrain from referring to his investigations and measurements of the specific heats of solids at extremely low temperatures, the results of which led to that important principle known as the Nernst Heat Theorem—the most valuable contribution to thermodynamics since the days of Clausius, Maxwell and Helmholtz.

"Mr. Chairman, it is a source of keen regret to all that Doctor Nernst is unable to be here today. We are, however, highly appreciative of the courtesy of His Excellency Baron von Prittwitz-Gaffron, the German Ambassador to the United States, in coming to us from Washington to receive on behalf of Doctor Nernst this medal and certificate. I have, Sir, the honor and pleasure of presenting to you Baron von Prittwitz-Gaffron."

The Medal, Certificate, and Certificate of Honorary Membership were then presented to the German Ambassador by the Acting President, in the following manner:

"Dr. Nernst cannot be with us in person today because of the marriage of his daughter in Berlin at this time. He is, however, admirably and delightfully represented by the Ambassador from Germany to the United States, Dr. von Prittwitz-Gaffron, who has kindly come from Washington to attend our Medal Day exercises and to receive The Franklin Medal and Certificate and Certificate of Honorary Membership in the Institute on behalf of Dr. Nernst. Your Excellency, I have much pleasure in presenting these symbols of honorable consideration to you, with the request that you transmit them to Dr. Nernst with our compliments."

He then said: "Ladies and Gentlemen, the Ambassador from Germany to the United States."

The Ambassador, in accepting the medal on behalf of Dr. Nernst, spoke as follows: "It is indeed a great honor for me to be present at the Medal Meeting of the distinguished Franklin Institute and to receive, on behalf of Professor Walther Nernst of the University of Berlin, the valuable distinction which has just been bestowed upon him. I beg to express on his behalf to the President and the Board of Managers of The Franklin Institute his highest appreciation and sincere gratitude for the Franklin Medal, as well as for the honorary membership of the Institute which has been conferred upon him.

"Professor Nernst has asked me to convey to you his deepest regrets that he has not been able to come to the United States to be present here today and to receive in person the distinction awarded to him. Professor Nernst hopes, however, that he may have the opportunity some time in the future to come over from Germany in order to offer to you personally his sincerest thanks.

"As representative of the German Republic I may be permitted to express how deeply honored not only German science but the German Nation as a whole is, by the fact that Professor Nernst is the second German scholar who has been presented with the high distinction of the leading Medal in Physics in the United States and the honorary membership of The Franklin Institute.

"Your distinguished Institution has thereby once more shown its conception of the universality of science, a concep-

tion which Goethe expressed in the true and simple words: 'Science and art belong to the world, before them the barriers of nationality disappear.' This spirit of scientific cooperation between the nations is very highly appreciated and understood in Germany, which stands for an international scientific community. We hope and trust that the spirit of an ever closer understanding and cooperation may be spread throughout the world in the mutual interest of progress for the benefit of humanity and the advancement of civilisation. In this work Philadelphia occupies a conspicuous place, which ever has been an international scientific center and where, long ago, the collaboration in the field of scientific research with the other nations was initiated by that great American, whose name your institution bears, Benjamin Franklin."

The Chairman: "Mr. Ambassador, on behalf of The Franklin Institute I thank you heartily for your marked kindness in coming to us today. Your presence adds much to this occasion."

To Dr. Charles F. Brush, Cleveland, Ohio.

Dr. James Barnes presented Dr. Brush for the Franklin Medal with the following statement: "Again, Mr. Chairman, the Board of Managers of The Franklin Institute on the recommendation of its Committee on Science and the Arts was unanimously of the opinion that a Franklin Medal be awarded to Doctor Charles F. Brush, Electrical Engineer, of Cleveland, Ohio, 'in recognition of his invention and development of the first successful arc light system for illumination and of the first practical storage battery.'

"Doctor Brush was born in Euclid, Ohio, in 1849. He was educated at the University of Michigan, receiving the degree of M.E. in 1869. In 1899 he received the Rumford Medal from the American Academy of Arts and Sciences and in 1913 the Edison Medal from the American Institute of Electrical Engineers. Doctor Brush was the pioneer in the scientific development of arc lights and of the necessary electrical apparatus in connection therewith. The same can be said of his work in connection with the storage battery. Both of these epoch-making developments are essential today in our daily pursuit of work for most of us and of pleasure for

a few of us. He is truly a great inventor and a great benefactor. Although almost four score years of age, Doctor Brush is still 'going strong' intellectually and physically. He cannot stop investigating and, like our daring aviators, he is plunging into unknown scientific regions—a field bristling with difficulties. You will hear about this in his paper this afternoon. America is proud of Doctor Brush and The Franklin Institute is happy to number one of its oldest and most faithful members as a Franklin Medalist. I therefore, have much pleasure, Mr. Chairman, in presenting to you Doctor Charles F. Brush."

The Chairman presented the Medal, Certificate and Certificate of Honorary Membership to Dr. Brush as follows: "Dr. Brush, it is particularly gratifying to us of The Franklin Institute to present to you a Franklin Medal and Certificate and a Certificate of Honorary Membership in the Institute in consideration of your epoch-marking inventions and your life of devotion to scientific advancement. We bespeak for you many years of continued health and honor among your fellowmen."

In acknowledgment, Dr. Brush said, "I thank you and The Franklin Institute."

After the presentation of the medals, the acting president made the following announcement: "In the absence of Dr. Nernst, Dr. Irving Langmuir of the General Electric Company, Schenectady, N. Y., a former student under Professor Nernst in Europe, one of the great contributors to the modern theory of atomic structure, has kindly come from Schenectady to Philadelphia in order to present today the paper, 'Physico-Chemical Considerations in Astrophysics' which has been prepared for this meeting by Dr. Nernst. I have much pleasure in presenting Dr. Langmuir." (The paper prepared by Dr. Nernst which was read by Dr. Langmuir appears on page 135 in this number of the JOURNAL of the Institute.)

In appreciation of his cooperation the Chairman said: "Dr. Langmuir, I thank you heartily in the name of the Institute for your kindness in coming here today."

The Chairman then announced: "We shall now have the second paper of the day, prepared by our newest Franklin Medalist, Dr. Charles F. Brush of Cleveland, Ohio, one of

America's greatest inventors." (The paper read by Dr. Brush appears on page 143 of this issue of the JOURNAL.)

The Chairman dismissed the meeting with the following statement: "Ladies and Gentlemen, we have been glad to have you with us at our Medal Day exercises and are appreciative of the interest and consideration which have caused your presence here. The meeting is now adjourned."

HALL OF THE INSTITUTE,
May 16, 1928.

Evidence for the Gravitational Displacement of Lines in the Solar Spectrum Predicted by Einstein's Theory. C. E. St. John. (*Astrophys. J.*, April, 1928.) By Einstein's theory wave-lengths of radiation starting in the sun's atmosphere should be somewhat longer than the wave-lengths of the same radiation originating on the earth. This displacement toward the red end of the spectrum is directly in proportion to the wave-length but in no case is it more than minute. For a wave-length of 3800 angstrom units it amounts to only .008 unit and for 6600 A it is .014 A.

In this paper comparison is made between the wave-lengths of 1537 spectral lines at the center of the sun's disc and 133 at its edge and the wave-lengths of the same lines in a vacuum source on the earth. It is of powerful evidential value that in not a single case was a terrestrial line discovered to have a longer wave-length. In a few instances no difference was found and in the others the difference was in the direction predicted by Einstein's theory. Most of the lines measured were due to iron but confirmatory results were obtained with 6 lines of silicon, 18 of manganese, 402 of titanium and 515 of cyanogen. For iron lines coming from the center of the sun's disc and originating 520 km. above the photosphere the mean displacement toward the red is .009 A., while the theoretical Einstein displacement is .0091 A. For lines from higher levels the shift is greater than the theoretical value and from lower levels it is smaller. To upward currents in the sun's atmosphere such differences are largely attributable. The observational work was done at the Mount Wilson Observatory. G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

FUTURE INTERNATIONAL BASIS FOR ELECTRICAL UNITS.

By amendment to the International Convention on Weights and Measures it has been provided that electrical units and standards shall be dealt with through the organizations which have jurisdiction over the fundamental units of Measurement. These organizations are the international General Conference, the International Committee, and the International Bureau of Weights and Measures. (See *The Technical News Bulletin*, No. 127, November, 1927.)

The seventh General Conference on Weights and Measures, held in 1927, approved the formation of a committee on electricity to advise the permanent International Committee on Weights and Measures on questions relating to electrical standards and systems of measurement. This advisory committee was limited to ten members, including a representative appointed by each of the national laboratories designated by the International Committee and additional Specialists named individually by that Committee. It was provided that a member of the International Committee should be chairman of the advisory committee and that a report should be rendered by it not later than March 1, 1929.

The national laboratories designated are the National Physical Laboratory of Great Britain, the Laboratoire Central d'Electricité at Paris, the Physikalisch-Technische Reichsanstalt of Germany, the Central chamber of Weights and Measures of the Union of Socialist Soviet Republics (Russia), the Electrotechnical Laboratory of the Department of Communications of Japan, and the National Bureau of Standards of the United States. Of the four additional members only two appointments have been announced. These are M. Chas. Guillaume, Director of the International Bureau of Weights and Measures, and Professor L. Lombardi of Rome, Italy. An American advisory committee has been formed to assist

* Communicated by the Director.

the Bureau of Standards in formulating proposals representing a consensus of the opinions held in this country. The organizations invited to take part and the representatives named as members of this committee are as follows:

National Academy of Sciences—Professor A. E. Kennelly.
American Institute of Electrical Engineers—Professor A. E. Kennelly.
American Physical Society—Professor Henry Crew.
National Electric Light Association—Dr. Clayton H. Sharp (Alternate—Mr. A. B. Morgan).
Association of Edison Illuminating Companies—Dr. Clayton H. Sharp.
National Electrical Manufacturers Association—Mr. W. J. Canada.
American Telephone and Telegraph Company—Mr. A. B. Clark.

The questions which these committees have before them may be considered as threefold, namely (1) the relative functions of the International Bureau and the several national laboratories in the future maintenance of the electrical units, (2) The particular values of the units to be adopted, (3) the methods to be used to assure the constancy of these units. These questions are, however, closely interrelated, and in particular the answers to the first two depend upon the last one.

The American Advisory Committee met at the Bureau of Standards on June 16, 1928, together with a number of members of the staff of the Bureau. After due consideration of the information available regarding the present status of electrical measurements, the Committee unanimously adopted the following resolutions:

1. *Resolved*, that in the opinion of this Committee, in view of improvements which are being made in absolute measurements, electrical standards should in future be based upon the absolute system of units.

2. *Resolved*, that in the opinion of this Committee, the functions which it is desirable to have the International Bureau of Weights and Measures undertake in connection with the electrical units, are as follows:

"(1) A central secretariat to arrange for systematic

exchange of Standards and compilation of results of intercomparisons thus made among the national laboratories.

"(2) A laboratory to which concrete standards representing the results obtained in the different countries may be brought for precise comparisons.

"(3) A repository for international reference and working standards with the necessary equipment so that other standards may be compared with these standards on request."

Resolutions of similar purport have been under consideration by committees of the American Institute of Electrical Engineers for some months, and were finally approved by the Board of Directors during the Denver Meeting, June 25–29, 1928. The official text of these resolutions has not been published, but it is understood that it is in print as follows:

WHEREAS, there is conclusive evidence that there are discrepancies between the statutorily established international electrical units (ohm, ampere, and volt) and the fundamental ohm, ampere and volt, which the international units were intended to represent, these discrepancies in the case of the ohm and the volt amounting to approximately one-twentieth of one per cent.; and

WHEREAS, differences of this magnitude are objectionably large in comparison with the precision required and now being attained in the construction and use of standards fundamental to all electrical measurements; therefore be it

Resolved, that the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake, as soon as possible, the additional researches necessary in order that legislation to reduce these discrepancies to within acceptable limits may be enacted in the near future.

And WHEREAS, the present electrical units are defined by statute in terms of material standards, namely, the mercury ohm and the silver voltmeter, which it is now known only approximately represent the absolute ohm and ampere and which experience has shown to have serious limitations, and

WHEREAS, such progress has been made in recent years in the art of making absolute electrical measurements in terms

of the fundamental units of length, mass, time, and space permeability that the accuracy and reproducibility of a system of electrical units realized by such absolute measurements would seem to be adequate for commercial, industrial and scientific purposes; and

WHEREAS, the legalization of the absolute ohm and ampere and the units derived from them (these units to be realized by the national standardizing laboratories) would avert the recurring proposals for revision of the values of the legalized units, and would establish the electrical units on a permanent legal basis: therefore be it

Resolved, that the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake as soon as possible, the additional researches necessary in order that the absolute ohm and absolute ampere based on the absolute volt, watt and other units derived from them, may be legalized in place of the international ohm and ampere and their derived units.

Resolved, further, that in order to avoid the confusion which would result from an interim use of new empirical units based on corrected values of the international units, the international electrical units should be continued in effect without any readjustment of values until such time as the practicability of legalizing the above-mentioned absolute units shall have been determined.

Even after national standardizing laboratories were established these arbitrary primary standards were considered the most practical basis for defining the units and for checking from time to time the values maintained by resistance coils and standard cells. Developments during the last twenty years have, however changed the situation materially. In the first place, the standards used purely for maintenance purposes have proved surprisingly dependable: in the second place, all scientific workers have come to depend upon the great national laboratories to supply certified standards, so that no other laboratory expects to set up independent reference standards; and finally, the experience gained in electrical measurements together with the refinements made in electrical theory have apparently made it possible to determine absolute

values for the ohm and ampere with an accuracy not less than that attained in reproducing the international units by the prescribed arbitrary primary standards.

The excellent performance of the modern wire resistance coil and standard cell makes it possible to maintain the units for many years with a certainty greater than the values can be reproduced by any single method. In actual practice whenever mercury ohm determinations have been made during the last twenty years, the results have been considered as agreeing with the wire standards within the limits of accuracy attainable by the mercury tubes, and *the values assigned to the wire standards have not been changed.* Similarly, the second unit actually maintained throughout that period has been the volt, represented by the standard cell: in fact no final agreement has ever been reached on the precise specifications for the silver voltmeter to represent the second international unit.

The logical conclusion seems to be to recognize the fact that the nominally accepted international system of reproducing the units has not worked in actual practice, but that out of experience there has developed a better system. This consists of highly dependable maintenance standards which will serve to maintain continuity and uniformity of values, these values being subject to change by international agreement only when the accumulated evidence of repeated determinations by all available experimental methods shows that there has been a drift or that the values assigned to the working standards are not exactly what they should be.

Looking forward to the need for the most accurate possible values of the electric units in the absolute system, the Bureau of Standards inaugurated some years ago a program of research in this field. This program is now being pushed forward more rapidly, and, although as a whole it must extend over many years, it is hoped that some preliminary results will be at hand before the report of the International Advisory Committee is due in March, 1929. In the meantime, the opinions of American technical societies, as recorded in the resolution quoted above, are being put before the International Advisory Committee. Representing as they do the unanimous action of the organization concerned, these recom-

mendations should have great weight, and the position of this country in these international relationships is correspondingly strengthened by this complete understanding and hearty coöperation between governmental agencies and the scientific, industrial and commercial organizations intrusted in the problem.

RADIO FADING IN THE BROADCAST RANGE.

For the past several months an investigation has been conducted by the Bureau of Standards to determine the factors contributing to the phenomenon known as fading. Special apparatus utilized in conjunction with radio receiving sets makes it possible to secure graphic records of the increase and decrease of signal strength such as are commonly experienced when listening to programs from distant stations at night. This apparatus, sufficiently sensitive to indicate variations smaller than the ear can detect, was used with receiving systems employing different types of antennas to analyze the manner in which the waves transmitted from a broadcasting antenna arrive at the receiving antenna.

The factors which may cause variations in the intensity of radio waves are complex, and a critical study of fading has suggested explanations of some of these factors.

Graphic records of a single selected transmission were made using identical receiving sets except for the antennas. The antenna systems used in the course of the investigation were (1) vertical antenna, (2) coil antenna directed toward the station being received, (3) coil antenna with planes at right angles to the direction of the transmission path, (4) combination of coil antenna and vertical antenna connected in such a way as to eliminate waves received directly from the station. Simultaneous records were made using two receiving sets with different types of antennas.

Examination of data from simultaneous measurements made with a soil antenna in maximum position and with a vertical antenna, respectively, indicated that for stations 165 to 1500 kilometers distant the same sort of fading occurred simultaneously in both antennas, but that for stations 13 to 53 kilometers distant similar fading characteristics did not occur simultaneously.

Records made with coil antennas at maximum and minimum positions showed that for a station 300 km. distant, for instance, there are considerable periods in which an increase of intensity in one antenna is accompanied by a decrease in the other. Often a relatively rapid and periodic fluctuation of small magnitude is found superposed on the longer period trend of the records. It was found that, for one station at least, this superposed, rapid fading of periodic type occurs with considerable regularity directly after sunset and lasts for approximately a half hour.

The results may be interpreted to mean that the waves do not reach the receiving antenna in the same position relative to antenna in which they start, i.e., their plane of polarization is changed. This change only takes place when the wave has been reflected. Several reflections from different points may take place, resulting in there being at the receiving station two or more waves which started at the same time from the transmitting station and traveled very different paths before reaching the receiving station.

More detail concerning these phenomena will be given in a paper to be published at a later date. Notice of this publication will be given in the *Technical News Bulletin.*

FIRE EXPOSURE CONDITIONS IN MASONRY-WALLED BUILDINGS HAVING COMBUSTIBLE INTERIOR CONSTRUCTION.

BUILDINGS of this class constitute a majority of the business structures in our towns and cities. The masonry walls afford protection to the building in case of fire in neighboring buildings, particularly with protected wall openings, and again they decrease the hazard to the surroundings when the given building burns, although freedom from collapse of enclosing walls not supported on adjacent construction cannot be promised after the interior floor construction has fallen.

The severity of fires in buildings of this type is of interest mainly as it concerns exposure to the surrounding buildings, to party and fire walls, and to protected containers located within the building, such as insulated safes and vaults. Previous tests made at the Bureau of Standards to obtain

information on the severity of building fires have simulated conditions in buildings having fire resistive interior as well as exterior construction that will withstand a complete burning-out of combustible contents and trim without collapse of major structural members, such as walls, floors, columns, and roof. Items relative to these tests have been given previously in this bulletin and the first technical paper giving the results with office and record storage occupancies has been published (Proceedings 14th Annual Meeting of the Building Officials' Conference, 1928; and *Quarterly* of the National Fire Protection Association, Vol. 22, No. 1; July, 1928). This interprets the results of burning-out tests in rooms having fire resistive enclosures and combustible contents from 13.1 to 55.4 lbs./ft.^{2} of floor area (105,000 to 440,000 B.t.u. per square foot) assumed uniformly distributed, in terms of hours of equivalent fire exposure in the standard furnace test used to rate the fire resistance of building materials, constructions, and devices.

In case of fires in buildings with combustible interior construction there is an initial period of fire exposure before floor and roof construction collapses the severity of which is measurable by the same means and in the same terms as that of fires in fire resistive buildings. Beyond the point of collapse of floors, roof, column, and wall constructions, the air temperatures, except immediately above the debris, go down to points presenting little hazard. The temperature in the debris continues, however, at higher points for long periods and is of interest as it concerns exposure to safes, vaults, and party and fire walls, that may be covered, partly covered, or in the contact with it. Temperatures measured in the debris from heavy furniture and high loaded shelves in the tests previously referred to indicated a more severe condition than that of the fire exposure above it, although the piles were not as high as would be expected from the collapse of several floors of a non-fire-resistive building. In building fires it is recognized that the most severe exposure for insulated safes and vaults is the prolonged heating in the ruins where water is not applied.

The lack of information on what is the severity of exposure under such fire conditions, led to requests that the bureau

include tests with such buildings in its work on intensity and duration of building fires. This matter was of particular interest to the Committee on Protection of Records of the National Fire Protection Association, as a basis for assigning suitable degrees of protection for records in buildings of given heights and combustible contents. The opportunity for conducting a test of this kind presented itself in connection with the Government building program in Washington that involved the razing of buildings on several squares. Two adjoining buildings, previously housing mercantile occupancies, one two stories 20 feet wide, the other five stories and 30 feet wide, both 75 feet long, were placed at the bureau's disposal through the courtesy of the Treasury Department. These buildings had brick walls and open wood-joisted floor and roof construction, the floors being of one inch boards on 3-inch-thick joists. Both buildings had open stair and elevator shafts, very few partitions, and generally presented conditions favorable for rapid spread of fire.

The buildings were loaded with waste lumber to give superimposed load of combustibles of 7½, 15, and 30 pounds per square foot of floor area for the front, middle and rear 25-foot sections, respectively, of all floors of the two buildings. Thirty-two insulated safes were located on the various floors, mostly along the walls. Most of them were donated by manufacturers and represented degrees of fire resistance from less than one hour to fully four hours of fire resistance as exposed in the standard furnace test. Five old safes were also included, three of which were supplied by the Post Office Department. Each safe was loaded with paper and in each was also placed maximum indicating thermometers. In all safes above the ground floor was also placed an alarm clock fitted with a trigger that would stop the clock movement when the position of the safe was disturbed, this being intended to indicate the time the safes dropped because of collapse of the supporting floor. About 50 thermocouples were inserted through the outside walls a few feet above the different floors and a similar number extended from hollow posts erected and anchored into the concrete floor slab near the ground level of both buildings. These thermocouples connected with an instrument room 100 feet to the rear of the buildings. The

rest of the buildings in the square as well as in the adjoining square on one side had been razed at the time of the test, the nearest building being approximately 200 feet away. To decrease the hazard to the surroundings, the side walls of the higher building were trussed together with rods above the roof line to delay the collapse of the walls, and new sheet steel roofing was placed over the old roofing to aid in holding down the volume of flame, hot gases, and brands that might escape during the height of the fire. At a conference held immediately before the test with safe manufacturers and others interested it was decided to continue this test to the point of cooling down of ruins without the application of water.

Fires were started at several points on the ground floor of both buildings at nearly the same time early on the morning of June 17, the time being chosen to avoid interference with the usual activities of the district in which the buildings were located. The day was clear with little or no wind. The fire spread rapidly up through the open stair and elevator shafts and within ten minutes nearly all portions of the two buildings were involved. In the course of 15 to 20 minutes the wooden floor joists began to burn through, followed by falling of safes. The greater number of safes fell in the period between 23 and 38 minutes. When the fire had been burning 28 minutes a section of the front wall of the larger building fell out. Portions of the other walls fell at intervals thereafter, until at the end of the first hour the greater portion of the walls above the first story in the small building and above the second story in the other building had collapsed. When the side walls of the 5-story building fell out, the falling brick work blanketed the 2-story structure and produced a prolonged heat exposure for the buried safes. After $1\frac{1}{2}$ or 2 hours it could be said that the buildings were burned down, but in the larger building there remained a large mass of debris that continued to flame for many hours.

The test involved a large amount of work in preparation, and observation during and after test. A complete report based on a full reduction of temperature and other data cannot be given at this time. However, it can be stated that the temperature rise during the initial portion of the test was more rapid than in the standard furnace test, 2000° F.

obtaining at several points within 20 minutes, and maximums between 2200 and 2400° F. at a few points within 40 minutes. After collapse of floor and roof constructions the air temperatures fell rapidly except at points immediately above the burning debris. The exposure in the ruins was more prolonged although less intense. Temperatures high enough to be prejudicial to the fire safety of the contents of safes obtained in different portions of the ruins for periods from a few hours to three days. The severity of the exposure to different safes varied greatly even in places where the safes were within a few feet of each other in the ruins. The test should therefore not be regarded as being in any sense a comparative fire test of safes, but rather one to determine the fire exposure conditions for such devices. It is expected that the test will yield data among others on the following points:

(1) The rapidity of spread of fire in open joisted buildings of the type tested;

(2) The rate of temperature rise and maximums obtaining before the interior construction collapsed as measured by thermocouples within mountings of size comparable with those employed for furnace temperature measurements in fire tests;

(3) The extent to which the rapid temperature rise produced explosive openings of safes as has been experienced in some fires;

(4) The time the safes dropped, this to be considered in comparison with the one-half hour or one hour duration of fire test before impact drop in the standard procedure for testing safes;

(5) The effect of the drop on the safe structure, and also the effect of impact from falling brick walls and similar heavy objects, this to be considered in comparison with the effect of the 30-foot drop on brick rip-rap in the specification test for safes;

(6) The effect on safe and contents of being covered, partly covered, or in contact with the hot debris after the fire;

(7) The percentage of safes involved that were fully covered, partly covered, in contact with, or clear of the hot debris;

(8) Air temperatures above the debris, this having a bearing on exposure to safes, and to party and fire walls;

(9) Temperature in the debris until cooling down, a matter of several days;

(10) Effect of the fire in producing collapse of building details such as enclosing walls and metal roof covering, the protection afforded neighboring buildings by these details and general hazard to surroundings created by the fire.

It might be added that the test created little hazard to the surrounding buildings with the weather conditions present. The temperature on the exposed wall of a temperary wooden shed located 110 feet from the burning buildings in a position to receive the maximum effect from radiated heat was apparently well below the ignition point for wood. The column of hot gases rose in such manner as to easily clear all surrounding buildings in its path. The only building that it might have affected was the Post Office Department building whose tower is of considerable height. However, the mild breeze present bore the column in a different direction. The test was marked by almost total absence of brand production. This might be owing to the general character of the contents consisting as they did of no lighter material than one inch boards as well as to the absence of wind. The steel roofing in the buildings functioned acceptably in the period 15 to 30 minutes in forcing exit of the hot gases mainly through the window openings, thus preventing a decided chimney effect. The tie rod through the side walls above the roof line apparently delayed major collapse of walls until the fire was a little past maximum intensity, when their fastenings pulled through the masonry. All walls fell outward caused by expansion near the inner surface from the fire. A similar effect has been observed in fire tests of unrestrained walls, although with 12-inch thick walls 11 feet high or 8-inch walls of similar height stiffened with plasters 8 inches thick, the deflections developed were not large enough to cause collapse.

COMMERCIAL STANDARD FOR CLINICAL THERMOMETERS.

WRITTEN acceptances, representing at least 65 per cent. of production by volume, and a majority of distributors and organized users, having been received by the commercial

standards unit of the Bureau of Standards, announcement has been made by the bureau that the commercial standard for clinical thermometers will become effective for the industry on October 1, 1928.

This standard was formally approved by a general conference of manufacturers, distributors and organized users, held March 30, 1928. The conference at that time agreed that production of new thermometers under this standard would begin October 1, 1928, and that one year (March 30, 1929) would be allowed for clearance of existing manufacturer's stocks. Annual revision of the standard was provided for through the appointment of a standing committee, representative of the entire industry.

The industry also authorized the promotion of foreign commerce in this commodity, which will be manufactured under provisions of the standard. It will be first translated into Spanish and Portuguese.

At the time the conference was held manufacturers present stated that the industry was determined to market only accurate and reliable clinical thermometers and to this end each thermometer would be certified by the manufacturer to the purchaser as complying in all respects with the requirements and tests required by the approved commercial standard adopted.

TESTS OF LARGE CONCRETE CYLINDERS.

THE data on the test of the group of concrete cylinders described in *Technical News Bulletin* Nos. 129 and 133 have been carefully analyzed, resulting in some interesting developments. It may be recalled that the cylinders were in the proportion of height equal to twice the diameter, the sizes being 2, 3, 6, 12, 18, 24 and 36 inches in diameter.

Comparison of test results readily showed that in general, throughout the tests, for any batch, the larger the diameter of the cylinder the lower the strength. The several factors influencing the strength were studied. These were: fabricating methods, curing conditions, testing machine speed, proportions and water-cement ratio. The 2-inch and 3-inch cylinders were made by one method, the 6-inch and 8-inch by

another, the 12-inch and 18-inch by another, which was slightly modified when applied to the 24-inch and 36-inch cylinders. It was found that for cylinders of different size and made of the same proportions, and by the same fabricating and curing methods, the strength was practically the same, and conversely every change in strength was accompanied by a change in fabricating method or a change in mix. As one example, the average strength of the 2-inch cylinders, which were of the same material and made in the same manner, by only $\frac{1}{4}$ per cent. The difference in cylinder size was therefore shown not to be responsible for the change in strength.

The rate of deformation of the cylinders varied considerably with the size of specimen, due mainly to the different specimen heights, coupled with the standard head speed. The rate of deformation of the 6-inch cylinders was approximately the rate of the 24-inch cylinders, yet the 6-inch cylinder strength was in each case markedly higher than the strength of the 24-inch cylinders, eliminating the difference in rate of testing deformation as the cause of the strength difference.

Due to the difference in strength of cylinders made from purportedly duplicate batches, the influence of increasing the size of the aggregate in the mix was not unconditionally determined. The best indications from the tests, however, are that the maximum strength is attained under the fabricating conditions of this group of test cylinders, with aggregate of maximum size of about two inches, the strength falling off with increase in size of aggregate. The strength with 10-inch aggregate is approximately 20 per cent. less than for 2-inch aggregate. The loss in strength may be reasonably allocated to the difficulty of causing the larger aggregate to be interlaid in the minimum volume, or with a minimum of voids.

USES OF GLUE IN THE PAPER INDUSTRY.

A HANDBOOK on the above subject, recently published by the Glue Research Corporation, contains a summary of the information gathered during the investigation of the uses of glue in the paper industry, by the research fellowship of the National Association of Glue Manufacturers at the Bureau of Standards. This was prepared by G. K. Hamill, research associate of the glue association who conducted the work.

The publication contains an outline of papermaking processes in general, information on uses of glue in beater sizing, surface sizing and coating, and a bibliography of publications dealing with these subjects.

Copies may be obtained from the Glue Research Corporation, 1457 Broadway, New York, N. Y.

TESTING PROCEDURE FOR DESTRUCTIVE AGENTS ON DETERIORATED COTTON TEXTILES.

DETERIORATED textile fabrics and yarns frequently present a very difficult problem to the textile chemist. This is especially so in the case of laundry materials where often accumulative deterioration occurs and the destructive agent is almost entirely removed by the laundry process. The problem then is the detection, identification, and estimation of chemicals of microscopic size.

The technical literature discloses that general methods are available for the most likely destructive agents. Other methods dealing more specifically with textiles are to be found in technical and trade publications in the textile field.

In connection with a study of deteriorated textiles it was necessary to formulate a procedure for estimating the maximum number of possible destructive agents with a minimum of sample available.

This procedure covers the analysis of a deteriorated cotton textile fabric for total silica, iron, aluminum, sulphates, total acidity, oxalates, soluble sulphates, soluble chlorides, and combined chlorides.

CHROME AND VEGETABLE TANNED SHEEP LEATHERS.

In connection with studies of the properties of leather six sheep skins were prepared by a tanner for the purpose of noting the effect of chrome and vegetable tanning processes on the strength and stretch of these leathers. Each skin was split down the back and one side of each skin was tanned by the vegetable process while the remaining sides were tanned by the chrome process. Each side of leather was cut into strips 1 x 6 inches, each of which was tested for strength and stretch. The results are listed below.

Sample.[1]	Tannage.[2]	Average thickness.	Percentage of stretch at 1000 pounds per square inch.	Percentage of stretch at failure.	Tensile strength.	Direction.[3]
		inches			lbs./in.	
1	C	0.035	—	47.0	2915	L
4	C	.038	—	42.0	3440	L
5	C	.034	25.5	43.8	2440	L
1A	V	.037	—	37.2	3325	L
4A	V	.044	—	36.5	4125	L
5A	V	.038	18.2	35.3	2995	L
2	C	.039	64.7	90.2	2305	C
3	C	.030	—	90.0	2120	C
6	C	.029	—	80.7	1595	C
2A	V	.038	61.4	85.8	2355	C
3A	V	.036	—	76.5	2515	C
6A	V	.031	—	87.3	1755	C

SUMMARY.

1A-4A-5A	V	0.040	—	36.3	3495	L
2A-3A-6A	V	.035	—	82.9	2280	C
1-4-5	C	.036	—	44.3	2900	L
2-3-6	C	.032	—	86.8	1995	C

[1] 1 and 1A, 2 and 2A, etc., sides of the same skin.
[2] C—Chrome, V—Vegetable.
[3] Direction of cutting test pieces, L—Lengthwise, C—Crosswise.

It will be noted that the sheep leather is much stronger in the lengthwise direction than in the crosswise direction regardless of the type of tannage and that the percentage of stretch is approximately double in the crosswise direction. The finishing methods may have an influence on these properties. The vegetable tanned leathers are stronger and stretch less than the chrome tanned leathers.

NOTES FROM LIGHTING RESEARCH LABORATORY, NATIONAL LAMP WORKS OF GENERAL ELECTRIC COMPANY.*

PHOTO-ELECTRIC SPECTROPHOTOMETRY.[1]

By A. H. Taylor, Physicist.

SPECTROPHOTOMETRY by visual methods is limited in accuracy by many experimental difficulties. This is especially true with respect to light near the ends of the visible spectrum, where the visibility of radiation is low.

In order to overcome these difficulties the author has adapted a photo-electric cell and vacuum-tube amplifier to a Hilger constant-deviation spectroscope. The image of a ribbon-filament tungsten lamp is focussed on the collimater slit, which is adjusted to a width of 0.2 mm. The eyepiece was altered to provide a 0.27 mm. slit, and a light-tight cabinet containing a gas-filled cæsium photo-electric cell is placed over the end of the telescope. Between the dispersing prism and the ocular telescope a housing was built. This contains a movable 45° mirror by means of which an opal-glass disk immediately above is imaged in the ocular telescope. Above this opal-glass is placed a movable tungsten lamp which illuminates it. The range of movement of this lamp is sufficient to make a change of 6 to 1 in the illumination on the opal-disk. Additional range is provided for by a sectored disk placed between the ribbon-filament lamp and collimater slit.

The cathode of the photo-electric cell is connected to the grid of a UV-199 vacuum tube. The anode is connected to the negative end of the filament through a 180-volt B battery, 45 volts of which are also used to supply the plate current. In the plate circuit is placed a 12,000 ohm rheostat, and a galvanometer and battery are connected between one end and the slider of this rheostat. When the voltage drop between these two points is just equal to the voltage of the battery in

* Communicated by the Director.
[1] To be published in full in the Jour. Opt. Soc. Am. and Rev. of Sci. Inst.

the galvanometer circuit, no current flows through the galvanometer.

When making a photometric balance the photo-electric cell is first exposed to the monochromatic light, and the rheostat is adjusted to make the galvanometer current approximately zero. Then the 45° mirror is moved into position to obscure the monochromatic light and substitute the image of the opal-glass disk. The movable lamp is adjusted until the galvanometer deflection is the same as before. If the balance remains unchanged when the monochromatic light is again exposed, the distance of the lamp from the opal glass is read off from a scale. When the spectral transmission of a colored glass is to be measured, the glass is placed between the ribbon-filament lamp and the collimater slit. Photometric balances are made at desired wave-length intervals with and without the glass interposed.

Measurements have been made on a number of color-filters which had previously been measured by the Colorimetry Section of the Bureau of Standards, with very satisfactory agreement in most cases. The sensitivity is sufficiently high to make measurements throughout the wave-length range from 4000 Å. to 7600 Å., and to measure with fair accuracy transmission-factors below one-half of one per cent., which would be practically impossible by visual methods. Very careful electrical shielding is necessary in order to obtain good results.

THE RELATION OF INTENSITY OF ILLUMINATION TO COLOR DISCRIMINATION.

By M. Luckiesh, Director.

THE appearance of a colored object is not fixed or invariable. It depends primarily upon the spectral character of the illuminant and spectral reflection of the object; and secondarily upon many other factors such as contrast, brightness, size, etc. For the purpose of color-standardization we contend that white light should be used. Rarely, however, is anyone interested in a color for itself and by itself. Nearly always the color of an object is significant only relative to that of another object. In color-grading the object is compared with an arbitrary standard.

In most cases of color-grading, any illuminant fairly rich in visible radiation of all wave-lengths is satisfactory if the level of illumination is sufficiently high. The level of illumination is a very important factor in color-work which has been unduly submerged by considerations of color quality alone. However, experience has shown us that, in most of the cases of color-grading in industry, it would be better to have a large amount of light of fair quality or spectral character than to have a meager amount of light of a daylight quality.

We have recommended an illuminant approximating daylight for the color-grading of many kinds of products, and have specified levels of illumination running into hundreds of foot-candles. For example, there are paint shops using 50 foot-candles, and in a tile factory color-grading is being done under 150 foot-candles. On every hand it appears that there are color problems which can be solved in this manner.

We recently recommended a lighting installation for a factory where fifty operators are engaged in color-grading of moderately dark, glossy buttons. Background is important in such work and we found a dull black to be best. Owing to specular reflection from the buttons, diffused light or light from a large source close to the work was unsatisfactory. We found that fairly concentrated light from one side, or both sides, minimized the annoyance of specular reflection. After experimenting with various natural and artificial illuminants, we concluded that the best level of illumination for these buttons, of low reflection-factor, was in the region of 300 to 500 foot-candles, and that the quality of light from tungsten Daylight lamps was satisfactory. As a result, we recommended a minimum of 100 foot-candles (preferably 200 or 300 foot-candles) obtained with tungsten Daylight lamps.

THE DURATION OF CLOSE VISION IN VARIOUS KINDS OF WORK.

By M. Luckiesh, Director.

PRODUCTION increases in our offices and factories when the level of illumination is increased, chiefly because the worker sees more quickly and with greater certainty than under low levels of illumination. Seeing is a partnership of vision and

lighting. Vision is the internal partner over which we have little control. Lighting is the external partner over which we have full control. In our study of lighting and its relation to vision, we find that improvements in lighting (increased levels of illumination, reductions of glare, increased contrast, etc.) increase the speed and accuracy of vision. However, in considering the influence of lighting on production, the question arises, "What percentage of the time does a worker actually use his eyes for close vision?"

In twenty industrial and office processes which we investigated, the average portion of time during which the eyes of the worker are engaged in close work was found to be about 70 per cent. These processes are found in ordinary offices, print shops, machine shops, and electric lamp factories. Obviously, some processes require the use of the eyes very much of the time, while others do not tax them so much. In only six of the twenty processes did the percentage of time requiring close vision fall below 50 per cent.; only three fell below 40 per cent.; and five were above 70 per cent.

These data indicate, as was to be expected, that increases in production, due to improvements in lighting, are likely to be different for various processes. They indicate further that close vision is required for a considerable percentage of the time in any of these representative processes, and that we may expect an appreciable increase in production from improved lighting in all our industrial processes where vision is required. Moreover, it is made clear by these experiments that increases in production already noted in factory tests are conservative values and should be easily equalled in most cases and exceeded in many.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE ELECTRICAL DEPOSITION OF RUBBER.[1]

By S. E. Sheppard.

THE negative charge on rubber particles corresponds to a contact potential of about 0.035 volt, and the particles have a mobility of about 2.7×10^{-4} cm. per second. The relation $n = c/k$, where n is the amount of rubber transported toward the anode per unit of current, c is the concentration of rubber in the latex, and k is the total conductivity of the latex, is approximately obeyed. To avoid porous deposits caused by the evolution of oxygen at the anode, depolarizers may be used. Fresh deposits are permeable, therefore thick coatings may be built up. Fillers, in the form of colloidal suspensions, are added to the latex, and are deposited along with the rubber.

NOTE ON A NEW EFFECT OF CHROMIC ACID DESENSITIZER.[2]

By E. P. Wightman and S. E. Sheppard.

CERTAIN plates made with inert gelatin were treated with chromic acid solution for Mr. A. P. H. Trivelli who observed that they apparently showed fog and sensitivity increase above the untreated plate. This phenomenon has been investigated further and it has been found that the increase in sensitivity passes through a maximum with time of treatment and finally for treatments of four hours or longer there is a small desensitizing effect. The phenomenon disappears when the plates are washed thoroughly in rapid running water prior to desensitizing. The effect may be due (1) to the liberation of bromine from soluble bromide in the plate by the chromic-sulfuric acid, on which bromine may act, according to a

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* Communicated by the Director.

[1] Communication No. 320 from the Kodak Research Laboratories and published in *Trans. Amer. Electrochemical Soc.* **52**: *47* (*1927*).

[2] Communication No. 339 from the Kodak Research Laboratories and published in *Phot. J.*, **68**: *201* (*1928*); *Sci. Ind. Phot.*, **8M**: *21* (*1928*).

hypothesis proposed by Hickman (*Phot. J.*, **67**: *34. 1927*) and E. P. Wightman and R. F. Quirk (*J. Frank. Inst.*, **204**: *731. 1927*); (2) to a lessening of the number of competing sensitivity specks by the chromic acid thus allowing the remaining specks to be more effective; or, (3) the specific action of chromic acid on something in the gelatin giving rise to a new sensitizer.

Acid permanganate does not produce the effect. This effect will be studied over a wider range of conditions.

THE FRANKLIN INSTITUTE.

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Mr. Paul Didier, Pittsburgh, Pa.
Mr. Herbert Lloyd, Philadelphia, Pa.
Col. J. A. Steinmetz, Philadelphia, Pa.

LIBRARY NOTES.

Recent Additions

American Concrete Institute. Proceedings of the Twenty-fourth Annual Convention, 1928. Volume 24. 1928.
BOREL, ÉMILE. Leçons sur les Séries Divergentes. Deuxième édition. 1928.
CHAZY, JEAN. La Théorie de la Relativité et la Mécanique Céleste. Tome I. 1928.
DYSON, F. Principles of Mechanism. 1928.
GEIGER, H., AND KARL SCHEEL, editors. Handbuch der Physik. Band 3. 1928.
HOFFMAN, JAMES D., AND LYNN A. SCIPIO. Elements of Machine Design. 1928.
KINGZETT, C. T. Chemical Encyclopædia. Fourth edition. 1928.
REED, EMERSON G. Essentials of Transformer Practice. Second edition, revised and enlarged. 1927.

BOOK REVIEWS

WIRELESS DIRECTION FINDING AND DIRECTIONAL RECEPTION. By R. Keen, B.Eng. (Hons.) Sheffield, A.M.I.E.E. Second and enlarged edition, 490 pages, 21 x 14 cm., cloth. London, Iliffe and Sons. Price, 21 shillings.

From a subject of deep theoretical interest since the classic researches of Hertz, directional wireless transmission is developing into a problem of rapidly increasing practical importance. Directional reception and direction finding as an aid to navigation, once perfected, it is generally conceded, will eliminate much of the hazard to navigation from the presence of fog or other causes which interfere with nautical observations.

Following a historical summary, the directional properties of aërial systems are first analyzed. Passing to the loop systems of modern direction finding, the installation, circuits and characteristics of the forms in which these systems are employed are discussed fully, among these the Bellini-Tosi system which employs two fixed loops at right angles to each other connected to a small loop radiogoniometer with which the readings are made. Besides the purely electrical features much attention is given the geometry of position finding and to maps adapted to those requirements. A chapter also is devoted to field and nautical astronomy. Among other important divisions of the subject which are critically examined are beacon transmitters, various transient phenomena, shore, ship and aircraft direction-finding installations. A bibliography to which references are made in the text is arranged in chronological form at the end of the volume. Especial mention should be made of the numerous diagrams and illustrations. Some of the latter are half-tone photographs, others are pen and ink sketches of unusual descriptive value and clearness. The chapter on tube amplifiers which was included in the first edition is omitted, the subject having outgrown available space. Nevertheless the work contains a comprehensive discussion of the essential elements of wireless direction finding and directional reception.

LUCIEN E. PICOLET.

MEMORIAL DES SCIENCES PHYSIQUES PUBLIÉ SOUS LE PATRONAGE DE L'ACADÉMIE DES SCIENCES DE PARIS, DES ACADÉMIES DE BELGRADE, BRUXELLES, BUCAREST, COÏMBRE, CRACOVIE, KIEV, MADRID, PRAGUE, ROME, STOCKHOLM, etc., etc., Directeurs: Henri Villat et Jean Villey.

Fascicule I, La Mecanique ondulatoire par Louis de Broglie Docteur ès Sciences. 54 pages, 25 x 16 cm., paper. Price, 15 francs.

Fascicule II, La Télémétrie Monostatique par Armand de Gramont, Docteur ès Sciences. 64 pages, 25 x 16 cm., paper. Price, 15 francs, Paris, Gauthier-Villars et Cie, 1928.

In many quarters, publishers of scientific works in recent years have been issuing series of monographs on various topics relating to some particular department of science, the whole forming a collection of encyclopedic character. Messrs. Gauthier-Villars have been very active in that field for many years, their Encyclopédie Scientifique des Aide-memoire, and the collection Scientia being well known to American readers. The project of the present series, their latest contribution of this kind, includes some seventy volumes each on a different topic of physical science under the general title *Mémorial des Sciences Physiques*. They form a

companion series to the previously established *Mémorial des Sciences Mathématiques* devoted exclusively to mathematical subjects of a most advanced type. These volumes are not original memoirs but rather a critical exposition of the latest progress and present state of the subject under discussion. The two volumes above noted are the first of the series to appear.

Doctor de Broglie's contribution deals with the abstract concepts of the wave-motion mechanics according to modern ideas of space and time. He shows how it has given new meaning to dynamic phenomena, the service it has rendered in the physics of the atom and how it constitutes a new mode of attack upon those profound problems already approachable by the theory of relativity. The volume constitutes a profound analysis and development of the ultra-modern concepts of mechanics which are applicable to the new atomic theory.

Doctor de Gramont's subject is of a more tangible character. Telemeters or range-finders are an indispensable part of the equipment of modern warfare which have assumed a variety of forms in the course of the development of a practical and accurate instrument adapted to the exacting service of field conditions. The work in general is devoted to the description of the optical system and its functioning of the short-base telemeter now widely used in all branches of artillery service. Several forms of these telemeters are described with an explanation of their optical systems, methods of calibration and practical data.

L. E. P.

A TEXTBOOK OF ORGANIC CHEMISTRY. By Joseph Scudder Chamberlain, Ph.D., Massachusetts Agricultural College. Second Edition Revised, 901 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1928. Price, $4.

The author who attempts to include in one moderate sized volume a comprehensive summary of organic chemistry has no easy task. He suffers really from the embarrassment of riches, for the amount of information now available concerning both the natural and artificial substances included under the term "organic" is enormous and is increasing with accumulating rapidity. The present volume contains a very large amount of information on all the important departments of organic chemistry. Of recent years the extensive development of bio-chemistry, as it has been called, especially in its applications to physiology and pathology has compelled a separation from the general chemical literature into specialized manuals for use more particularly in medical schools. Incidentally it may be mentioned, though it has no great relevancy to the present criticism, that a strong tendency has been developed to assign the teaching of bio-chemistry and the writings of its textbooks to those having degrees not in medicine but in science or philosophy. We find as a result of this that a considerable proportion of the faculties of our leading medical schools contain teachers that have not been trained in medical science. It is not appropriate to discuss here the advisability of this method. It is being carried out, and until some definite result, favorable or unfavorable, is manifested it will be unwise to give a positive opinion.

Turning to the work in hand which, being a second edition, has thus given evidence of its suitability, the descriptive matter begins as might be expected with that well-known typical molecule, methane, "the baby figure of the giant

mass of things to come." Practical information is scattered liberally through the volume in connection with the descriptions of compounds and the development proceeds as usual in textbooks of this character. A noticeable point of difference which will probably be noted more and more in manuals of this type is the treatment of the proteins in connection with the amino-acids following immediately after the starches and sugars. Heretofore we have always had these complex compounds treated at the end of the volume, often somewhat superficially because the great majority of chemists are only superficially familiar with them. Research has brought these proteins much more into the light as regards composition and we may expect much greater information from the active research now being pursued.

The volume presents therefore a very satisfactory account of all the basic phases of organic chemistry and will serve well for the student in that field. It is excellently printed with extensive presentation of structural formulas, a detailed table of contents and a good index.

HENRY LEFFMANN.

LEÇONS SUR LES SÉRIES DIVERGENTES. Par Émile Borel, Membre de l'Institut, Professeur à la Sorbonne, Directeur honoraire de l'École normale supérieure, avec le concours de George Bouligand, Professeur à la Faculté des Sciences de Poitiers. Second edition, 260 pages, 25 x 16 cm., paper. Paris, Gauthier-Villars & Cie., 1928. Price, 40 francs.

The influence of Professor Borel's "Leçons" which first appeared in 1901 has done much to stimulate activity in the study of divergent series and their application. In preparing this second edition, M. Bouligand has adhered to the general plan of the original work, yet including an account of recent progress in setting forth the origin of the processes of summation, their general characteristics and the conditions for their concordance. Stress has been laid on applications which reveal the relation of the subject to other theories of analysis. For example in the third chapter a consideration of trigonometric series brings into view two ideas which are essential to the foundation of summation processes, namely, mean value and factors of convergence. The work is addressed to the pure mathematician rather than to the reader who seeks directly applicable mathematical data. Beginning with a historic general review, the chapter headings are: I. Asymptotic series. II. Continued fractions and the theory of Stieltjes. III. The theory of summable series. IV. Summable series and analytical expansion. V. Expansion in series of polynomials. VI. (Appendix) Modern Development of the theory of divergent series.

L. E. P.

THE A. C. COMMUTATOR MOTOR. By C. W. Olliver, B.Sc., E.S.E. (Paris). xi–281 pages, illustrations, plates, 8vo. New York, D. Van Nostrand Company, 1927. Price, $7.50.

The alternating-current system as a method of power-supply with its inter-communicating net-work which now include wide areas of service is gradually eliminating the direct-current motor from the field of quantity-supply and with it, the sometimes inevitable but often avoidable commutator trouble. The one important exception is in railway engineering where the direct-current motor still prevails, but part of this condition, the author suggests, may be chargeable to "bureaucratic engineering," not uncommon in public utility organizations.

Whatever may be the surrounding circumstances and causes, the alternating current has come very much into its own and it is in order to provide motors that are capable of utilizing this current which have the same desirable flexibility and efficiency as has been attained in the direct-current motor.

The author believes that the alternating-current commutator motor affords an almost perfect solution to the problem, not perhaps so much by itself as when combined with the more usual induction motor. His book is in two distinct parts. The first contains all the analytical treatment of the subject while the second is devoted to a non-mathematical exposition of the principal applications of the commutator motor. After an introductory review, a study of commutation at considerable length is made. Having surveyed this important detail which the author believes has caused unfounded prejudice against the A. C. commutator motors, he proceeds to the theory of the simpler forms of single-phase and repulsion commutator motors. This analytical treatment covering the polyphase motor as well. The next chapter dwells upon the characteristics of the three-phase motor and explains as simply as possible what actually takes place in a machine of that kind. Then follows a chapter on cascaded sets and power-factor correction which includes a study of the influence of the power-factor, an analytical study of the induction motor and commutator motor combination, a description of various compensated motors and recent developments in power factor correction and speed regulation of induction motors. The second part on practical applications covers a well illustrated account of applications to cranes and hoisting appliances, single phase traction, the application of commutator motors to rolling-mill drives and to a number of other typical purposes. Both the analytical part and the descriptive matter represent the latest advances made by continental engineers and their methods of analysis. Much of the analytical matter and the project of writing this illuminating treatise were inspired, the author states, by lectures of Professor Marius Latour at the Ecole Superieure d'Electricite of Paris. L. E. P.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 282. The Performance of Several Combustion Chambers Designed for Aircraft Oil Engines, by William F. Joachim and Carlton Kemper. 12 pages, illustrations quarto. Washington, Government Printing Office, 1928. Price, 10 cents.

Several investigations have been made on single-cylinder test engines at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics to determine the performance characteristics of four types of combustion chambers designed for aircraft oil engines. Two of the combustion chambers studied were bulb-type precombustion chambers, the connecting orifice of one having been designed to produce high turbulence by tangential air flow in both the precombustion chamber and the cylinder. The other two were integral combustion chambers, one being dome-shaped and the other pent-roof-shaped. The injection systems used included cam and eccentric driven fuel pumps, and diaphragm and spring-loaded fuel-injection valves. A diaphragm-type maximum cylinder pressure indicator was used in part of these investigations with which the cylinder pressures were controlled to definite values. The performance of the engines when equipped with each of the combustion chambers is discussed. The data presented show the performance for speeds from 600 to 1,800 R.P.M.

The results obtained indicate that aircraft-type oil engines with suitably designed combustion chambers and fuel-injection systems may be operated at speeds around 1,800 R.P.M. without encountering excessive explosion pressures. At a speed of 1,600 R.P.M. and with a fuel quantity giving 15 per cent. excess air in the cylinder, a maximum I.M.E.P. of 119 pounds per square inch was obtained with a fuel consumption of 0.43 pound per I.HP. per hour. The maximum cylinder pressure was 740 pounds per square inch. A minimum fuel consumption of 0.26 pound per I.HP. per hour at an I.M.E.P. of 52 pounds per square inch and 1,600 R.P.M. was obtained with a cylinder head having a bulb-type pre-combustion chamber. The maximum cylinder pressure was 560 pounds per square inch.

It is concluded that an increase in the specific power output of the high-speed aircraft oil engine depends upon the ability to obtain higher mean effective pressures and an improvement in the mechanical efficiency of the engine. The best performance for the tests reported was obtained with a bulb-type combustion chamber designed to give a high degree of turbulence within the bulb and cylinder.

Report 283, A Preliminary Investigation of Supercharging an Air-Cooled Engine in Flight, by Marsden Ware and Oscar W. Schey. 11 pages, illustrations, quarto. Washington, Government Printing Office, 1928. Price, ten cents.

This report presents the results of tests made by the National Advisory Committee for Aeronautics in a preliminary investigation of the effects of supercharging an air-cooled engine under airplane flight conditions.

This investigation comprises the first of its kind that has been conducted and for which results have been published.

Service training airplanes were used in the investigation equipped with production types of Wright J engines. An N.A.C.A. Roots type supercharger was driven from the rear of the engine.

In addition to measuring those quantities that would enable the determination of the climb performance, measurements were made of the cylinder-head temperatures and the carburetor pressures and temperatures. The supercharging equipment was not removed from the airplane when making flights without supercharging, but a by-pass valve, which controlled the amount of supercharging by returning to the atmosphere the surplus air delivered by the supercharger, was left full open.

With the supercharger so geared that ground-level pressure could be maintained to 18,500 feet, it was found that the absolute ceiling was increased from 19,400 to 32,600 feet, that the time to climb to 16,000 feet was decreased from 32 to 16 minutes, and that this amount of supercharging apparently did not injure the engine.

Report No. 284, The Comparative Performance of Roots Type Aircraft Engine Superchargers as Affected by Change in Impeller Speed and Displacement, by Marsden Ware and Ernest E. Wilson. 14 pages, illustrations, quarto. Washington, Government Printing Office, 1928. Price, ten cents.

This report presents the results of tests made by the National Advisory Committee for Aeronautics on three sizes of Roots type aircraft engine superchargers.

The impeller contours and diameters of these machines were the same, but the lengths were 11, 8¼, and 4 inches, giving displacements of 0.509, 0.382, and 0.185 cubic foot per impeller revolution. The information obtained serves as a basis for the examination of the individual effects of impeller speed and displacement on performance and of the comparative performance when speed and displacement are altered simultaneously to meet definite service requirements.

According to simple theory, when assuming no losses, the air weight handled and the power required for a given pressure difference are directly proportional to the speed and the displacement. These simple relations are altered considerably by the losses.

When comparing the performance of different sizes of machines whose impeller speeds are so related that the same service requirements are met, it is found that the individual effects of speed and displacement are canceled to a large extent and the only considerable difference is the difference in the power losses which decrease with increase in the displacement and the accompanying decrease in speed. This difference is small in relation to the net power of the engine supercharger unit, so that a supercharger with short impellers may be used in those applications where the space available is very limited without any considerable sacrifice in performance.

Report No. 286, Aërodynamic Characteristics of Airfoils—V. 49 pages, illustrations, quarto. Washington, Government Printing Office, 1928. Price, twenty-five cents.

This collection of data on airfoils has been made from the published reports of a number of the leading aërodynamic laboratories of this country and Europe.[1] The information which was originally expressed according to the different customs of the several laboratories is here presented in a uniform series of charts and tables suitable for the use of designing engineers and for purposes of general reference.

It is a well-known fact that the results obtained in different laboratories, because of their individual methods of testing are not strictly comparable even if proper scale corrections for size of model and speed of test are supplied. It is, therefore, unwise to compare too closely the coefficients of two wing sections tested in different laboratories. Tests of different wing sections from the same source, however, may be relied on to give true relative values.

The absolute system of coefficients has been used, since it is thought by the National Advisory Committee for Aëronautics that this system is the one most suited for international use and yet it is one from which a desired transformation can be easily made. For this purpose a set of transformation constants is given.

Each airfoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for designing purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent. of the chord length, the latter also serving as the datum line. The shape of the section is also shown with reasonable accuracy to enable one to more clearly visualize the section under consideration, the outside of the heavy line representing the profile.

The authority for the results here presented is given as the name of the

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[1] A previous collection of airfoil sections numbered 1 to 623 and Charts 1 to 16 may be found in N. A. C. A. Reports Nos. 93, 124, 182, and 244.

laboratory at which the experiments were conducted, as explained under abbreviations, with the size of model, wind velocity, and year of test.

LA THÉORIE DE LA RELATIVITÉ ET LA MÉCANIQUE CÉLESTE, Par Jean Chazy, Chargé de Cours à la Faculté des Sciences de Paris. Vol. I, viii–261 pages, 25 x 16 cm., paper. Paris, Gauthier-Villars & Cie., 1928. Price, 60 francs.

The aim of this work, which is the development of a course of study at the Faculté des Sciences de Paris in 1927, is to set forth as clearly as possible the theory of relativity in its relation to celestial mechanics assuming on the part of the reader the preparation of a student who has followed courses in the differential calculus and in mechanics.

The first chapter deals with the elements of the calculus of variations, a method to which the usual courses of instruction give no attention, and the definition and conceptions concerning such quantities as ds^2 which enter into the current anguage of the theory of relativity. In the second chapter the author states the law of gravitation reckoning from the ds^2 of Schwarzschild. Applying this law to movements of the planets with respect to the sun, he calculates the advancement of the corresponding perihelia and obtains notably the celebrated value 42.9 seconds per century for the planet Mercury. In the third chapter, the author adopts the law of gıavitation thus defined to the method of the variation of the constants under the classical form of the theory of perturbations. He examines analogous laws of gravitation stated in classical mechanics to explain the observed advancement of the perihelion of Mercury. He studies the corrections to duration of newtonian revolutions and more particularly applies these corrections to the passage of Mercury over the solar disc.

The fourth and fifth chapters, due to a digression justified by the purpose of the work, are devoted, the one to a résumé of the investigations of Le Verrier and of Newcomb relating to the errors of the movements of planets with relation to the newtonian theory, the other to an exposé of the different hypotheses advanced to explain the three disagreements obtained by Newcomb. The last chapter covers the examination of the law of the propagation of light defined by the ds^2 of Schwarzschild from which is derived the remarkable result of 1.74 seconds for the deviation of luminous rays tangent to the solar globe.

A second volume will dwell particularly upon the origin of the ds^2 of Schwarzschild and how Einstein was led to formulate the law of gravitation defined by this ds^2. He will calculate other different effects of the theory of relativity which can be compared with observations in a more or less proximate future, of the effect of rotation of the central body upon the movement of a mass gravitating in its vicinity, the movement of precession along the orbit of the Earth, and cosmological applications.

L. E. P.

REPORT OF THE COMMISSION APPOINTED TO INVESTIGATE THE FAILURE OF THE ST. FRANCIS DAM. 21 pages, 30 plates, 8vo. Sacramento, California State Printing Office, 1928.

The failure of the St. Francis Dam in California added one more to the long list of serious disasters from such constructions. The Commission appointed by the Governor of California to investigate the cause and course of the disaster has presented in this pamphlet a full detailed account. This information will be of

great value and importance to engineers engaged in the construction of such works, which are becoming more and more necessary in our modern industrial and city life. The necessity of impounding large masses of water for general supply and power purposes is now great.

The verdict of the Commission is that the dam itself was properly constructed but that the natural-rock foundation was defective, being composed partly of a mica schist of inferior firmness.

H. L.

CHEMICAL ENCYCLOPÆDIA. By C. T. Kingzett, F. I. C., F. C. S. 8vo, vii–807, illustrations. D. Van Nostrand Company, New York, 1928. Price, $10.

The fact that this work has gone to the fourth edition within comparatively brief time shows that it has met a very important want in chemistry, and that it has merit. The great development of industry in chemistry has caused a material increase in the size of the volume, about two hundred pages having been added as compared with the third edition. Care and attention has been given to corrections that have been necessary and matters relating to chemical applications and chemical engineering have been incorporated. A broad field has been covered since the text includes items of pure, physical and applied chemistry, together with general descriptions of both inorganic and organic compounds, and the more important chemical terms and theories.

In consequence of the comprehensive character the work is valuable, not only to professional chemists in both the research and commercial phases, but also to lawyers and other professional persons who may be engaged in litigation or discussions in which chemical questions arise. It is stated in the preface that there is no other work in existence that gives such an extensive range of condensed up-to-date information concerning chemistry and industry. It is well printed and well written. It is much to be regretted that the great increase in the cost of printing compels publishers to place such high prices upon books of this character.

HENRY LEFFMANN.

PRINCIPLES OF MECHANISM. By F. Dyson, A.C.G.I., B.Sc. (Hons.), A.M.I., Mech.E., Lecturer in Mechanical Engineering at the City and Guilds (Engineering) College, Imperial College of Science & Technology, London. viii–296 pages, 21 x 14 cm., cloth. Oxford University Press, American Branch, New York, 1928. Price, $4.25.

The design of a machine is always a tentative process in which the choice of the component mechanisms rests with the judgment of the designer. There is no analytical process to guide the selection of the most suitable mechanism to effect a required motion, but a sound knowledge of the principles which govern the operation of simple mechanism is the nucleus, about which a vast collection of amplification may be derived.

The present author has not adhered strictly to purely kinematical principles. He has judiciously introduced some dynamical ideas which, if they depart from the strict orthodoxy of pure mechanism, aid materially in giving the exposition of the subject a practical meaning of applicable value. Most of the usual topics found in works on mechanism which deal with the abstract consideration of

motions apart from the forces which accompany them are included. Here, force, work and friction are considered and applied to an explanation of the efficiency and non-reversibility of mechanisms. Velocity and acceleration determinations are described of a variety of linkages adequate to ordinary demands, tooth gears, ordinary and epicyclic trains receive a very satisfactory condensed treatment. Among the examples of epicyclic trains is discussed the Ford two-speed reverse gear, and other trains of that type. Belts, pulleys, friction, fly wheels, governors, cams and balancing receive an equal amount of attention. Worked-out examples constitute an important feature of the text and in addition a liberal number of examples of practical character is provided at the end of each chapter. Without being exhaustive in character, this book represents a thorough and rational treatment of the principles which govern the functioning of mechanisms.

Lucien E. Picolet.

Elements of Machine Design. By James D. Hoffman, M.E., and Lynn A. Scipio, M.E. 327 pages, illustrations, 21 x 14 cm. Boston, Ginn & Company, 1928. Price, $3.80.

A number of treatises on machine design are already extant which very fully and satisfactorily to many classes of readers treat the details of the subject. The appearance of another work must be to meet some particular curriculum requirements or should possess some very marked advantage of arrangement of subject matter. The principal objective of this work, the authors state, is to illustrate by the use of typical examples of design, methods of attack whereby the student may most expeditiously derive the greatest amount of information.

The book is in two main divisions. In the first, fundamental principles of machine design are laid down. The second division is devoted to design applications of the principles which are discussed in the first division. The first part includes a generally satisfactory presentation of the usual topics of machine design. There is a large amount of descriptive information, and the formulas used are stated without derivation but adequately explained by illustrative examples. Reference to active works direct the reader to whatever further analytical information may be desired. A discussion of springs for some reason not stated has been entirely omitted. The second part includes examples of toggle-joint presses, designs of a punching and shearing machine, an overhead travelling crane, a Scotch boiler and a number of diagrammatically illustrated assignment sheets for the exercise of inventive capacity. Some of these appear a bit ambitious for a novice. Thus several forms of bent wire paper clips in common use are shown. The problem calls for the design of cams, connecting levers and properly shaped dies to produce from a spool of wire the forms indicated. The work appears to be an adaptation of less analytical character of the first-named author's earlier work on the same subject in collaboration with Professor Charles H. Benjamin. The subject is generally well covered and should prove an efficient text for school work, but there are many individual readers who would derive greater profit from the type-forms of standard machines illustrated in fuller detail. An album of typical structural detail of modern machines used in manufacturing is indeed more urgently needed by the student of machine design than another book on the principles of the subject.

Lucien E. Picolet.

THE ESSENTIALS OF TRANSFORMER PRACTICE, THEORY, DESIGN AND OPERATION. By Emerson G. Reed, Bachelor of Science in E.E., Member of the American Institute of Electrical Engineers. An Associate Editor of Pender's Handbook for Electrical Engineers. Second Edition, Revised and Enlarged, 401 pages, illustrations, 22 x 14 cm., cloth. New York, D. Van Nostrand Company, Inc., 1927. Price, $5.

Like other components of the almost universally used alternating current system, the transformer has received its due share of analysis and refinement. Theoretical and practical questions over a long term of years of development have been settled and processes of design have assumed the stable conditions of an important industry. A code of practice of the processes of design and proved methods of operation of these apparatus is accordingly desirable and possible and the authors' presentation of a systematic and deductive account of the theory of the transformer, its design and operation is an adequate response to a need of a logical guide for the designing or operating engineer or for the student.

Both in topic and treatment, the book is of a type that will prove especially useful to those who desire rational methods in specific problems of design. There are numerous diagrams and charts but no illustrations of apparatus. Such illustrations useful as they are in surveying the field of previous accomplishments could scarcely be included without unduly increasing the size of the volume, besides the designing engineer usually has such information on file; the student must have recourse to periodical literature, trade publications or other descriptive sources for structural detail.

A condensed historical review precedes the discussion of the subject proper. After surveying the general principles of the transformer and defining the relation of impressed and delivered electromotive forces and primary and secondary currents, the author discusses copper and iron losses and relations derivable from these losses. These analyzed, the results are applied to the deduction of relations of losses to the cost of a transformer. The next step is a consideration of type (shell or core) and the effect of changing the proportions of a transformer. The application of these principles is now made to carrying out in detail the design of various types of transformers in which the tabulated results of six different computations are given for a transformer of given capacity with variant values of coefficients previously discussed. Many other topics, among them efficiency, regulation, heating, insulation and mechanical stresses are treated in the same thorough fashion as the preceding.

The liberal number of numerical examples which are included throughout the work to illustrate the analytical deductions are helpful to almost any class of readers and especially to students. There are few references to original papers and no bibliography, an adjunct of recognized utility in modern technical works. A small amount of space might with advantage have been devoted to a key to the notation employed to facilitate the use of the work as a reference manual.

L. E. P.

FIXATION OF ATMOSPHERIC NITROGEN. By Frank A. Ernst, Fixed Nitrogen Research Laboratory, U. S. Department of Agriculture. 154 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928. Price $2.50.

Nitrogen is a sort of Doctor Jekyll and Mr. Hyde among the familiar gases. Inert in its free state as it is in the atmosphere, it shows a wide range of chemical activities in combination. Its compounds are extremely numerous and of very varied characters, in some cases, for instance, strychnine, the compound may be permanent, but in the common high explosives we have extreme susceptibility to violent action. The element is an important one in biologic chemistry, essential to the formation of tissues in animals and plants. It has therefore functioned largely in agriculture and it has been found that one of the most useful forms is as nitrate. The world has relied for many years upon the remarkable and extensive deposits of sodium nitrate in the rainless area of Chile. Inventive genius has been applied to the problem of fixing the nitrogen of the air in some active compound and several different methods have developed; of these the present day operation is principally the formation of ammonia, and it appears from the book in hand about 722,000 tons are fixed annually as ammonia. It is well worth noting by Americans that of this amount 500,000 tons are fixed in Germany.

In the present book there is presented a comprehensive summary of the several methods now in use for nitrogen fixation. Descriptions are clear and detailed; all those interested in this very important problem will find set forth in very satisfactory form the present state of this industrial operation. Excellent illustrations of important plants add to the value of the essay. The theory and practice of each process is given. The user of the book will, therefore, be able to keep up to date in all phases of nitrogen fixation. The book is well printed, on good paper. Its low price will enable chemists generally to add it to their libraries.

HENRY LEFFMANN.

BIBLIOGRAPHY OF AËRONAUTICS, 1925. Prepared by the National Advisory Committee for Aëronautics. 189 pages, 8vo. Washington, Government Printing Office, 1928. Price, fifty cents.

This work covers the literature published from January 1 to December 31, 1925, and continues the work of the Smithsonian Institution issued as volume 55 of the Smithsonian Miscellaneous Collections, which covered the material published prior to June 30, 1909, and the work of the National Advisory Committee for Aëronautics as published in the Bibliography of Aëronautics for the years 1909 to 1916, 1917 to 1919, 1920 to 1921, 1922, 1923, and 1924.

As in the previous volumes, citations of the publications of all nations have been included in the languages in which these publications originally appeared. The arrangement is in dictionary form with author and subject entry and one alphabetical arrangement. Detail in the matter of subject reference has been omitted on account of the cost of presentation, but an attempt has been made to give sufficient cross references to facilitate research in special lines.

THE INDUSTRIAL CHEMISTRY OF THE FATS AND WAXES. By E. P. Hilditch, D.Sc. F.I.C. University of Liverpool. With introduction by E. F. Armstrong, D.Sc., F.R.S. xi–461 pages, 8vo. New York, D. Van Nostrand Company, Inc., 1927. Price, $6.

The literature concerning the fats and waxes (in the former term the oils are included) is now enormous, due to the great number of forms and the wide range of applications. The present work is limited to the industrial chemistry and therefore, the dietetic problems, which constitute in themselves a feature of great extent and complexity, are left out of consideration. It is interesting to note that the fundamental nature of the fats was elucidated more than a century ago, while the structural chemistry of the other two branches of the food triad, proteins and carbohydrates has only lately been approximately solved.

Dr. Armstrong, in his introductory note, says that the chemistry of the fats and waxes has received very little attention during the past twenty-five years, although they are substances of great importance. This may be due to the fact that their structure has been long known and attention has been directed to the study of their derivatives and to the modifications that may be brought about in them. The analytic problems have been the subject of a great deal of study, on account of the liability of them to adulteration and substitution. One of the derivatives, "glycerol," a name which is agreeable to see much used in the book, has acquired very high importance in many ways, but especially in the manufacture of explosives.

The book is not a textbook of chemical engineering, but is intended as a connecting link between an essay on the pure chemistry of the subject and the technology. In any work, however, it is now impossible to keep strictly to a special treatise and the text will frequently be carried over into associated fields. Such departures, however, are infrequent, occurring only when necessary, so that the book is especially constructed to serve the works-chemist rather than the consulting or commercial analyst. There is plenty of literature available for these latter.

The book was printed in Great Britain, and shows the rather heavy ink impression that usually characterizes British books, but it is excellent presswork. British reviewers sometimes complain of the lighter impression in American books, calling it "sepia" rather than black.

HENRY LEFFMANN.

THE STORY OF GEOLOGY. By Allan L. Benson. viii–297 pages, illustrations, 8vo. New York, Cosmopolitan Book Corporation, 1928.

The author of this book is known best as an active member of the socialist party, and as its candidate for president in 1916. Entering into literature as an author of a scientific treatise, the critic naturally scrutinizes the text with care. Geology, it is true, is hardly yet an exact science; there is much about it that is established, but from time to time, material changes take place in the attitude of its promoters. The fact is as Darwin pointed out and vividly expressed, the geologic record is so imperfect that great care must be taken in interpreting the information we have. It is well worth while for any one about to become interested in geology to read Darwin's chapter on "The imperfection of the geologic record."

At the very initiative of this book we meet with a rash statement that leads us to doubt its safety as a guide for those not familiar with the details of the science. We are told that "The earth under our feet and every star we can see with a glass, including the most distant star, are composed of the same substances." The statement is much too rash; it may be true, but we do not know if it is. We find that there is a good deal of similarity in the composition in the heavenly bodies, but analysis has not progressed nearly so far as to justify such a broad statement as the above, nor is it indeed important to consider such a question. Geology is a study of the earth, not of the universe, and there is no use going outside of the proper limits of the subject when the amount of material to be handled is very extensive.

This book, being intended for general reading, gives, of course, prominent expression of the attractive and striking features of the earth's surface. It is impossible in the limits allotted to the reviewer to consider all the details presented. The author accepts without question the community of descent between man and the apes, and the general succession of plant and animal forms as commonly taught. A large number of illustrations are given, all of which are of excellent quality and will serve to interest the reader and give information as to the many interesting sights on the face of the earth. There is, apart from the somewhat dogmatic attitude especially concerning the theory of evolution, an attitude which may be expected in one holding the author's views on the fundamental subjects, but there are nevertheless many interesting descriptions and explanations. Perhaps the book is strictly a discussion of "the face of the earth" rather than geology proper, but it is not necessary to cavil at such distinction. The book is well printed, of clear type, and as noted above, profusely illustrated.

HENRY LEFFMANN.

PHOTOCHEMICAL PROCESSES. By George B. Kistiakowsky, Princeton University. 270 pages, 8vo. American Chemical Society Monograph. New York, The Chemical Catalog Company, Inc., 1928. Price, $5.50.

The fact that light has a wide range of action has been known for many years and has been utilized in the many phases of photographic procedure now so abundantly featured in our everyday life. "You push the button and we do the rest" has given pleasure to millions of human beings both at home and in travel. That silver salts are especially affected by exposure to light was known tc Glauber in the days when Pepys was writing his now famous (and in some respects infamous) diary, but many observers were inclined to believe that the result was due to heat or air. It was Heinrich Schulze, who in 1707 demonstrated that the darkening of silver salts was due to light alone. Since his time a vast industrial, artistic and scientific accumulation has been made, and active research is still going on, much of it financed by corporations manufacturing photographic supplies.

The present work is an inquiry into the phenomena of photochemistry from the standpoint of the quantum theory. A very large amount of data has been collected and set forth in a careful and scientific manner. The latest phases of the quantum theory are applied and the highly technical and, to most persons very abstruse principles are presented. One turns with interest to the discussion

of the most active storm-center of photographic physio-chemistry, namely, the latent image. Much printer's ink has been expended in arguing on this topic. The author leans to the theory originally propounded by Carey Lea and supported by Lüppo-Cramer, that the light acts by freeing a modicum of silver which is adsorbed on the silver halide. It has been proved that the action of light on silver halides results in the escape of a minute amount of the halogen, but this effect is in agreement with the view that a sub-halide is formed, as well as the other theory. It is remarkable that in all the discussions of the latent-image problem no account is taken of the fact that the whole of the halide may be removed by strong hypo, the plate thoroughly washed, appearing perfectly clear, and the image easily brought out in complete detail. Further in the reviewer's own experience, the latent image remains for years. The development after fixing is accomplished, as is well known, by the precipitation of metallic mercury instead of silver (although it is stated that silver also can be employed). The mercury evaporates in time but a reprecipitation can be made. There seems to be no discussion of this subject in this book although some space is given to the theories concerning the latent image. The photosensitiveness of mercurous iodide is also not mentioned, at least no reference is found in the index. This effect was pointed out in a German Journal in 1836, but not specially investigated. The present reviewer has made some experiments on the substance and it has seemed that by incorporating the iodide with gelatin and spreading the mixture on a plate, a more rapid effect is obtained. In this case the action probably depends on the liberation of an atom of mercury with formation of mercuric iodide. It is probable that all substances are somewhat affected by light.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Technical Drawing. A manual for evening classes and junior technical schools by George Edwin Draycott. 232 pages, illustrations, 12mo. London and New York, Oxford University Press, 1927, price $2.00.

Mechanics for Engineers, Statics and Kinetics, by Julian C. Smallwood and Frank W. Kouwenhoven. 185 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1928, price $2.50.

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CURRENT TOPICS.

Variations in the Quantity of Ozone Contained in the Atmosphere. JEAN CABANNES and JEAN DUFAY. (*Journal de Physique et le Radium*, Sept., 1927.) Fabry and Buisson have demonstrated the existence in the upper atmosphere of a layer of ozone which plays an important part in the absorption of solar radiation. Were all of this gas reduced to normal pressure and temperature it would form a layer about 3 mm. thick but this equivalent depth changes from day to day in an irregular way. At Oxford Dobson and Harrison have made a study of its variations. Their results based on observations made daily for ten months show that the local atmospheric pressure is closely connected with the variations and indicate the possibility of seasonal changes. One of the authors is carrying out at Montpellier, France, a similar series of observations that will finally give not only the thickness of the ozone layer but also its elevation.

Fortunately for the scientific patience of the writers of this paper they will not need to wait a decade or two until they have material accumulated by their own industry. They turn to the *Annals* of the Astrophysical Observatory of the Smithsonian Institution and there find ready to hand data on the transparency of the atmosphere above Mount Wilson in California and Calama in Chile. At Mount Wilson the observations were conducted from May to October or November while in Chile they were made in all seasons. For both stations the factors of transparency are listed for ten wave-lengths ranging from .35 to 1.60 μ. From these data on transparency it is possible by using a graphic method to derive the thickness of the equivalent ozone layer. This gas shows selective absorption for waves ranging in length from .48 to .65 or .70 μ. Upon the transparency of the air for wave-length .60, which lies close to the maximum absorption of ozone, the calculations of the thickness of the layer of this gas have been based. The error in the thickness amounts to about .06 cm. Over Mount Wilson the greatest thickness found was .45 cm. for May, 1908, and June, 1914, and the least .21 cm. for October, 1909. In general the thickness of the layergrows less from June to October. The average

thickness for May, obtained by using all records for that month from 1908 to 1920 inclusive, is .337 cm., and for the succeeding months it is: June, .375; July, .323; August, .313; September, .300; October, .303; November, .270 cm. These results agree well in their direction with those derived from the observations of Dobson and Harrison in Oxford.

The series at Calama extends only from July, 1918 to July, 1920. The greatest average thickness for any month was for July, 1918, .333 cm., and the least for May, 1919, .259 cm. The variation in value is much less than over Mount Wilson. There is some evidence of a seasonal variation of small amplitude at Calama but opposite to that which takes place at Mount Wilson. This difference is perhaps due to the two stations lying on opposite sides of the equator.

"The curve of annual means of the thickness of the ozone layer differs considerably from those which represent the annual values of the number of sunspots and the solar constant. There seems, however, to exist a certain relation between the thickness and solar activity, since there was little ozone during the years that preceded 1913, the year of minimum activity."

G. F. S.

Some Experiments with Sound Waves of High Frequency. S. R. HUMBY. (*Proc. Phys. Soc.*, Vol. 39, Pt. 5.) The late Lord Rayleigh used as a source of very short sound waves a bird call or whistle of high pitch. This is difficult to use in the absence of some means of applying a steady air pressure. "It was therefore decided to test the possibilities of a telephone receiver placed in the plate circuit of a three electrode vacuum tube which was producing oscillatory currents of the desired frequency. This arrangement has the great advantage that its frequency is regular and is under control. Also the intensity of the sound can be varied by means of a resistance box used to shunt the telephone earpiece." Frequencies between 4,000 and 16,000 were obtained. Effects were detected by a sensitive flame or occasionally by the ear. Some of the experiments will remind older members of The Franklin Institute of what they saw at a lecture by Walter LeConte Stevens in the '80's of last century. (He died only a short time ago.)

Data on the kinds and the use of sensitive flames are furnished. "The range of frequencies to which a jet responds

is often very small—in one case five separate responses were measured between 4,260 and 4,640." Reflection of sounds of high pitch was shown across a room by means of metal mirrors. The creeping of sound waves around a whispering gallery was demonstrated. When waves are reflected from a plane surface those going toward the surface interfere with those coming from it and stationary waves are formed. It is such stationary light-waves that Otto Wiener fixed photographically about 1889. Mr. Humby explored the space occupied by the standing waves by the use of two types of sensitive flames. One kind showed least disturbance at the loops and the other at both loops and nodes. "It is interesting to hear the variations of loudness of sound throughout a room when the note is switched on. The room is found to be filled with stationary nodes and loops, for, as the ear is moved, the sound swells out and diminishes in a fascinating way. It was found that with the one-valve circuit used and 60 to 200 volts high tension the stationary waves could be located by a sensitive flame at distances up to 15 feet from the source."

The waves were reflected at almost grazing incidence from a plane surface and came to interference with other waves travelling in almost the same direction that had not been reflected. A sensitive flame showed definitely this acoustical analogy of Lloyd's mirror fringes. In addition fringes from the interference of waves coming from two different sources and other interference effects like those due to the Heaviside layer obtained in wireless transmission were demonstrated. Diffraction effects were detected for a slit and for a straight edge as well as with a grating. With a zone plate marked alternate increases and decreases in intensity were found as the successive zones were removed.

G. F. S.

Rigidity and other Anomalies in Colloidal Solutions. EMIL HATSCHEK. (*Proc. Royal Inst. Great Britain*, No. 121.) Let a cube of elastic solid be held between two planes one of which is fixed while the other is moved to one side by a force acting parallel to itself. A shear is produced and owing to its rigidity the deformed solid will return to its original form upon the disappearance of the distorting force. If the cube is transparent and isotropic it becomes doubly refracting when sheared. This "accidental double refraction" affords a sensitive test for the existence of strains

and has been been used to study experimentally their extent and amount in cases that present difficulties to computation from theory. The modulus of rigidity, the force producing unit deformation on a cube of unit dimensions, is some tons per sq. cm. for steel and about 100 g./sq. cm. for gelatin jelly. All true solids possess rigidity but no normal liquid has it. If the space between two planes be filled with a liquid and a tangential force be applied to one plane, the other being fixed, the plane continues to move as long as the force acts. The force requisite to maintain the plane in motion is proportional to the area of the planes, to the velocity gradient between the fixed and the moving plane and to the coefficient of viscosity of the liquid, which is the force per unit area requisite to keep up unit velocity in the moving plane when the planes are a unit distance apart. In all liquids as in the case of molasses the viscosity increases in cold weather. The coefficient is remarkably independent of the velocity with which the moving plane travels. "The viscosity of water has been measured by a number of observers over a range of velocity gradient varying in the ratio of 1 to 10,000 and has been found quite constant."

A study of the viscosity of colloidal liquids made clear that they manifested bewildering anomalies. Order was introduced by the use of an instrument in which the liquid was contained between two coaxial cylinders one of which was rotated. The results for gelatine solutions are characteristic. As the angular velocity of the rotating cylinder increases the coefficient of viscosity grows less and tends to become constant for high velocities. At the smallest angular velocities the coefficient is two or three times as large as at high velocities. Many colloidal solutions of very different kinds have been studied and all show the same general comportment in respect to viscosity. To explain this marked divergence from the behavior of normal liquids Freundlich has suggested that colloidal solutions possess not only viscosity but also rigidity. "If this assumption is true, the liquid—to put the matter colloquially but picturesquely—will have to be stretched as well as sheared. It can be shown mathematically that the result will be what has been found experimentally, viz., that the viscosity decreases with increasing shear." The author has discovered a colloidal solution that displays rigidity to a remarkable extent—"a very dilute, about one-quarter per cent. solution of ammonium oleate, a soap familiar as material for soap

bubbles." The space between two cylinders was occupied by this solution. The pivoted inner cylinder was given a spin. Had it been surrounded by ordinary liquid it would have slowed up and finally come to rest, but with the ammonium oleate it came to rest and then started to rotate in the opposite direction somewhat as if it had been rotating in contact with a hollow cylinder of elastic rubber.

The moduli of rigidity of several colloidal solutions have been determined. All have no rigidity above 40° C. The viscosity of ammonium oleate is very temperamental changing constantly and over long periods of time. For colloidal solutions the moduli of rigidity are measured in milligrams per sq. cm. instead of in grams as is the case for gelatine jellies. Furthermore the modulus increases with the age of the solution. For example in the case of a solution of mercury-sulphosalicylic acid its modulus was eight times as great after 23 days as it was after 20 hours. In respect to the manifestation of rigidity the colloidal solutions examined showed much diversity. One shows rigidity if prepared hot but not if made at room temperature. Some, when heated to the temperature at which rigidity disappears regain upon cooling that property as it existed when the solution was old while others upon cooling behave as freshly made solutions. The phenomenon of double refraction occurs in most colloidal solutions.

G. F. S.

A New Mass-Spectrograph and the Whole Number Rule. F. W. ASTON. (*Proc. Roy. Soc.*, A 772.) The first mass-spectrograph, set up in the Cavendish Laboratory in 1919, could separate lines derived from masses differing by about 1 in 130. Its accuracy of measurement was 1 in 1,000 approximately. "These capabilities sufficed to determine with fair certainty the isotopic constitution of over 50 elements, and to demonstrate that, with the exception of hydrogen, the masses of all atoms could be expressed as integers on the scale O = 16 to one or two parts in a thousand." It was not till 1925 that this instrument which had rendered such iconoclastic service was dismantled. A need was felt for an instrument that would better separate the mass lines of the heavier elements and furnish more accurate information on divergences from integral mass numbers. A study of these divergences is of great value because they throw light on the structure of atomic nuclei. Costa in Paris, using an instrument with an accuracy of 1 in 3,000, in 1925 published excellent measurements on this matter. Now

Aston is ready to describe his perfected apparatus and to cite results obtained with it. The essential improvements consist in "doubling the angles of electric and magnetic deflection, and sharpening the lines by the use of finer slits placed further apart. The new instrument has five times the resolving power of the old one, far more than sufficient to separate the mass lines of the heaviest element known. Its accuracy is 1 in 10,000." The positively charged particles traversed a distance of 15 cm. in a magnetic field that could be extended to 20,400 gauss. At one stage in the development of the apparatus it gave discordant results even after months spent in an endeavor to make it work correctly. The solution of the difficulty was at last suggested by Sir Ernest Rutherford.

For the expression of masses the mass of the neutral oxygen atom has been taken as 16, as is commonly the case in chemical literature. While the existence of an isotope of oxygen has been suggested by Blackett's experiments on the disintegration of nitrogen nuclei under the impact of alpha rays, still up to the present the weight of evidence is on the side of the simplicity of oxygen. Of course if this element later is proved to be possessed of an isotope, a revision of masses established by the mass-spectroscope will be necessary. The mass of the electron is taken as .00054, when the oxygen atom is 16.

It is commonly believed that atoms have nothing else in their structure than electrons and protons, hydrogen nuclei. Since the proton has a positive charge and the electron an equal negative charge it follows from the neutrality of the atom that there are in it as many positive protons as negative electrons. The hydrogen atom consists of one proton with one electron. Hence the masses of all atoms should be integers, the mass of the hydrogen atom being unity. The first mass-spectrograph showed that this was not the case, even for individual isotopes. "The theoretical reason adduced for this failure of the additive law is that, inside the nucleus, the protons are packed so closely together that their electromagnetic fields interfere and a certain fraction of the combined mass is destroyed, whereas outside the nucleus the distances between the charges are too great for this to happen. The mass destroyed corresponds to energy released, analogous to the heat of formation of a chemical compound, the greater this is the more tightly are the component charges bound together and the more stable is the nucleus formed. It is for this reason that measurements of this loss of mass are of such fundamental importance, for by them we may learn something of the actual structure of the nucleus, the atomic number and the mass number being only concerned with

the numbers of protons and electrons employed in its formation." The "packing" fraction of the atom of an element is got by dividing the actual departure of its mass from a whole number by the mass number of the element. Since the mass number is the same as the number of protons in the atom the packing fraction expresses the "Gain or loss of mass per proton when the nuclear packing is changed from that of oxygen to that of the atom in question." It is expressed in parts per 10,000.

The results obtained with the new apparatus fall into two classes, additional information about isotopes and measurements of packing fractions. Under the first head sulphur has been proved to be triple consisting of atoms having masses of 32, 33 and 34. "S^{34} appears to be about three times as abundant as S^{33}; the two together amounting to about three per cent. of the whole." Calculation shows that this composition gives for the average atomic weight of the mixture a number close to the chemically determined atomic weight. Furthermore for tin no less than eleven isotopes have been discovered. Their mass numbers in the order of their intensities are 120, 118, 116, 124, 119, 117, 122, 121, 112, 114, 115. Two isotopes of xenon, hitherto in doubt, have been definitely shown to exist. Mercury presents six isotopes as follows, 198 (4), 199 (5), 200 (7), 201 (3), 202 (10) and 204 (2). The numbers in parentheses give the relative intensities. In all measurements of precision were made on 18 elements from hydrogen to mercury. This involved an examination of 51 types of atom, whose masses are now known to 1 or 2 in 10,000.

When the packing fractions are plotted against the mass numbers as abscissas it is seen that for all but light atoms they lie on a single curve. "Starting at hydrogen with a large positive packing fraction the curve drops rapidly, crosses the zero line in the region of mass number 20 and sinks to a minimum value of about -9 in the region of mass number 80. It then rises again and recrosses the zero line in the region 200. There is no marked periodicity." The packing fraction of hydrogen is (multiplied by 10^4) 77.8; of helium 5.4; of lithium 20.0. The largest negative value is for krypton, -9.4.

G. F. S.

Sugar Cane Specialists Will Explore New Guinea for Disease-Resistant Varieties. Having come to the conclusion that New Guinea is the native home of sugar cane, the United States Department of Agriculture, has organized an expedition under the leadership of Dr. E. W. Brandes, sugar plant specialist, which will use an airplane in searching the unexplored wilds of the Island for disease-resistant cane varieties that may prove valuable to the industry in Louisiana and other parts of the South.

Doctor Brandes will sail from San Francisco April 12 accompanied by Dr. Jakob Jesweit who was formerly chief of sugar p ant breeding work in Java and now of the University of Wageningen, Holland; and Richard K. Peck who will pilot the plane. Peck acted as pilot for the Stirling Expedition to Dutch New Guinea under the Smithsonian Institution in 1926–27. These men will be joined at Honolulu by C. E. Pemberton, entomologist of the Hawaiian Sugar Plant Association Experiment Station, and proceed to Port Moresby, the base of the expedition on the southeast coast of New Guinea.

The plane, a Fairchild cabin type, will be furnished by B. G. Dahlberg, president of the Celotex Company, makers of synthetic lumber from sugar-cane bagasse, who is also interested in sugar-cane plantations in Florida and Louisiana. Equipped with pontoons for landing on rivers, lakes or other bodies of water, the plane will make possible the exploration of the interior portions of the Island otherwise inaccessible or difficult to reach. The study is expected to take from six to eight months. The Australian Government is coöperating to make the expedition possible and successful.

While the idea of such an expedition has been under consideration for the past six years or more, it has not been possible to bring it about until recently. Depression in the sugar-cane industry of Louisiana and other parts of the South resulting largely from the declining yields caused by mosaic and root diseases has given impetus to the project.

The most feasible method of improving the production of sugar cane in the South is by the use of varieties that are resistant or tolerant of these diseases. Some favorable results have already been accomplished by the introduction of several improved varieties developed at the Proefstation Oost Java, the experiment station maintained by private planters in Java. These varieties have given such satisfactory performance in tests during the past six years that specialists have been encouraged in the work. More than 170,000 acres were planted in Louisiana last fall with varieties recently introduced from Java.

Because sugar cane is propagated by cuttings instead of with seed, it will be necessary to adopt a method of keeping the collected canes in a growing condition until shipment can be made to the United States. A propagation garden will be established for the purpose at Port Moresby where newly collected specimens will be sent at intervals and planted. When the expedition is ready to return, cuttings will be taken from the propagating garden and shipped to Arlington Farm, Rosslyn, Va., for replanting in the department's sugar-cane greenhouses where they will be kept under observation for a year.

Under an improved method of propagating sugar cane introduced by Doctor Brandes, it is possible to increase the supply of cuttings from an original specimen about 20 times as rapidly as under the present commercial method. An illustration of the rapidity with which a commercial supply of planting material may be developed is seen in the fact that cuttings for the 170,000 acres planted last fall were produced from a few canes within four years.

Process for Manufacturing Genuine Maple Flavoring Product Devised. (U. S. Department of Agriculture, Press Service.) A process for manufacturing a true maple flavoring product, which when mixed with ordinary sugar sirup will make a reconstituted table sirup essentially the same as the commercial product, has been perfected by John W. Sale and J. B. Wilson, chemists of the Food, Drug and Insecticide Administration of the Department of Agriculture.

The process has been patented and has been dedicated to the public. Already one large manufacturer of flavoring products has taken steps to put the new flavor on the market.

The new flavor may be used by confectioners, bakers, ice cream manufacturers, and housewives, or by any others who use flavoring products. An excellent sirup can be made at home merely by adding the flavor in suitable proportions to a gallon of ordinary sugar sirup of proper density. The reconstituted table sirup will possess the delightful aroma and flavor of the original maple product.

All flavoring extracts on the market at the present time which purport to be "maple flavor" are synthetic products and even though they are harmless must be branded as "imitation maple" to meet the requirements of the Federal Food and Drugs Act. Most of them are made from a number of ingredients, the principal one in most formulas being fenugreek seed, an Old World plant of the bean family sometimes known as Greek hay seed. Other ingredients often used in making synthetic maple flavor are elm bark, celery seed, hickory bark, coffee, chicory, and vanillin.

No one has heretofore succeeded in preparing a genuine maple flavor—at least no flavor that is more concentrated than maple sugar. Maple sugar represents a maximum concentration of 1.3 parts maple sirup to 1 part maple sugar. All previous efforts toward the development of a true maple flavor have been along the lines of extracting the flavor itself. The process devised by Sale and Wilson, on the other hand, removes the sugar (sucrose) leaving nothing but the flavoring constituents. The sugar is precipitated by mixing a quantity of barium hydroxide with a

maple sugar solution such as maple sirup, partially concentrated maple sirup, maple sugar solution, or a combination of any two or more of these maple products. Subsequently, the excess barium reagent is completely eliminated.

The flavor thus recovered from 40 gallons of ordinary maple sirup can be so concentrated that it will be contained in 1 gallon of the concentrated flavoring product. Removal of the sugar also greatly enhances the keeping quality of the flavoring product, sugar being a highly fermentable substance. A by-product of the process is a sirup which is desirable for table or other uses.

Earth-Resistivity Measurements in the Copper Country, Michigan. W. J. ROONEY. (*Ter. Mag. and Atmos. Elect.*, Vol. 32, Nos. 3 and 4.) Much attention has recently been given to the connection between the physical properties of the earth's crust and its geological structure for the purpose of learning to locate oil, ore and mineral deposits. In the present research the Department of Terrestrial Magnetism and the Michigan College of Mines coöperated in studying the resistivity of the earth in the Upper Peninsula, where the geological structure is well known.

Wenner has shown that if four contacts equally spaced in a straight line are made with a large mass of a substance and if an electric current flow from one end contact through the mass to the other end contact then the potential between the inner pair of contacts divided by the total current is proportional to the resistivity of the material. The resistivity can be computed if the difference of potential current and distance from one contact point to the next be known. As the distance between contacts is increased the current penetrates more deeply into the earth and any change in the character of the material traversed by the current is revealed by a corresponding change in the resistivity obtained by applying the formula. It is the material near to the line of contacts that has the preponderating effect in determining the mean resistivity. Material as far away as the distance between adjacent contacts has little influence on the resultant resistivity.

In a series of measurements made near a drill hole so that geological structure might be known the average resistivity of a cm. cube in ohms was 5750 when the steel rods forming the contacts were driven in the earth 10 ft. apart. As the distance from one rod to the next increased the resistivity grew rapidly becoming a maximum of 82,000 ohms for a separation of 25 ft. This was interpreted to mean that at first the current was practically confined to the humus laden soil at the surface. When the rods were farther apart it penetrated to the underlying coarse drift. A further sepa-

ration to 50 ft. brought the resistivity down to 36,500 while still further separation caused it to rise slowly, becoming 81,800 when the rods were 200 ft. from one another. It is clear that beyond 25 ft. the current penetrated into a layer of small resistance, no doubt underground water. Beyond 50 ft. rock showed its presence by the increase in resistivity. Drill hole records located the rock 64 ft. below the surface.

By the same method the resistivity of several kinds of rock was measured. In general trap and other volcanic rocks had a resistivity from 5 to 20 times as great as that of porous sedimentary varieties. Very strange results were got by applying the method to a block of Calumet and Hecla conglomerate about 20 ft. long. These were however consistent with the presence of copper in the mass.

G. F. S.

The Optical Analogue of the Compton Effect. C. V. RAMAN and K. S. KRISHNAN. (*Nature*, May 5, 1928.) Two photographs are reproduced. The first shows the spectrum of light from a quartz mercury vapor lamp and the second that of the light scattered from toluene, the incident light being that of the first photograph. The second print shows several lines that are absent from the first. By the use of light filters it was found that the occurrence of these additional lines was dependent upon the presence in the incident light of certain lines or groups of lines having shorter wave-length. "Thus the analogy with the Compton effect becomes clear, except that we are dealing with shifts of wave-length far larger than those met with in the X-ray region." It is suggested "that an incident quantum of radiation may be scattered by the molecules of a fluid either as a whole or in part, in the former case giving the original wave-length, and in the latter case an increased wave-length." G. F. S.

The History of the Franklin Tree, Franklinia alatamaha. EDGAR T. WHERRY. (*Jour., Washington Acad. Sciences*, March 19, 1928.) "The Franklin tree is one of the few members of the Camellia family (Ternstrœmiaceæ or Theaceæ) which have survived the climatic and geographic changes of late Tertiary and Quaternary times on the North American continent. Considerable interest has been shown in this plant during recent years; largely owing to the fact that it has apporently become extinct in its native place, and is preserved only in cultivation." John Bartram discovered it near Fort Barrington, Georgia, in 1765. Eight years later his son William Bartram, who had accompanied his father at

the time of this visit, went back to the spot and, according to his cousin Humphrey Marshall in his Arbustum Americanum, 1785, "had the pleasing prospect of beholding it in its native soil, possessed with all its floral charms; and bearing ripe seeds at the same time; some of which he collected and brought home, and raised several plants therefrom, which in four years' time flowered. William Bartram has chosen to honor it with the name of that patron of sciences, and truly great and distinguished character, Dr. Benjamin Franklin. The trivial name is added from the river, where alone it has been observed to grow naturally." William Bartram testifies to its rarity in nature thus: "We (he and his father) never saw it grow in any other place, nor have I ever seen it growing wild in all my travels, from Pennsylvania to Point Coupè, on the banks of the Mississippi, which must be allowed a very singular and unaccountable circumstance." In 1790 a nephew of Humphrey Marshall found the tree still growing wild at the original spot. Though careful and repeated search has been made by competent persons no one has found it growing wild since 1790. There is reason to believe that at least part of the Georgia colony of Franklin trees was shipped to England and a fire may have finished the destruction. That the species persists at all is due to the survival of one specimen that Bartram transplanted to an acid part of his famous garden in Philadelphia. Nurserymen obtained plants but few succeeded until it was found that the tree does best in acid soil. Dr. F. V. Coville, who made this discovery, now has thriving trees in the nursery in Whitesbog, N. J. The tree is nearly sterile to its own pollen. "There are several specimens in old Philadelphia gardens, all apparently derived from the Bartram tree. One or two nurseries near New York City have supplied plants to estates in that vicinity, but they obtained their stock in the first place from Thomas Meehan and Sons, who utilized Bartram's garden as their original source of cuttings. The single tree at Chevy Chase Circle, Washington, D. C., also came from Meehan's. The hope may be expressed, however, that some day a descendant from another ancestor will be discovered, and the cross-pollination and production of seedlings in quantity may then become possible, representing the final step in the permanent preservation of this interesting plant."

G. F. S.

The Use of Photo-Electric Cells for the Photometry of Electric Lamps. T. H. HARRISON. (*Trans. of the Optical Soc.*, Vol. 28, No. 4.) Both sodium and rubidium cells were used in making a comparison between the accuracy attainable by their use and that

got by using the human eye. In four general comparisons the eye was found to be the less accurate. In spherical color matching the cells were five times as accurate, in mean spherical intensity measurements two times, in directional color matching five times and in directional intensity measurements nearly twice as accurate as the eye.

G. F. S.

The Problem of Artificial Production of Diamonds. C. H. D. (*Nature*, May 19, 1928.) It is easy to convert diamonds into graphite at high temperatures but the greatest difficulties bar the path of the converse transformation. Little is to be learned in regard to the genesis of diamonds from the way they occur in nature, but the assumption has often been made that they have been formed under high pressure. Henri Moissan's experiments were directed by this belief. He melted pure iron with sugar charcoal by the electric arc and cooled the molten mass rapidly in cold water, relying upon the contraction of the iron for the development of high pressures. Acids, oxidizing mixtures and fused potassium hydrogen fluoride dissolved the iron and, presumably, all minerals save diamond. There remained tiny crystals identified as diamonds by their optical properties and by giving CO_2 on combustion. Silver was used in the place of iron with the same final results. Crookes obtained similar crystals from the explosion of cordite in a bomb where the pressure rose to 8,000 atmospheres.

Sir Charles Parsons, whose presence at the Centenary of The Franklin Institute in 1924 is recalled with great pleasure, in his Bakerian lecture in 1918 reported the results of his own extensive series of experiments. He found that carbon, either liquefied or vaporized at a pressure of 15,000 atmospheres failed to crystallize as Crookes and Moissan held that it would, that in Moissan's work great pressure was not caused by quenching molten iron, that the application of a pressure of 100 tons per sq. in. to the molten iron resulted in the production of a smaller mass of crystals than in quenching, and, finally, that the presence in the iron of magnesium, chromium, silicon and aluminium as impurities augments the crystal residue which scarcely existed when commercially pure iron was used. He recognized the extreme difficulty of identifying the crystals left after treatment. Because of the uncertainties that adhere to Moissan's results, H. M. Duncan, who worked with Parsons, has made a study of the analytical methods involved. Spinels are hard to dissolve, he asserts, and optically may easily be taken for diamonds if they are small. "Whenever Moissan's experiments with cast iron have been repeated, although many particles

resembling diamond in appearance have been obtained, they have never stood the Combustion test." Parsons and Duncan have repeated the work of others who believed themselves successful in producing diamonds, but in no instance could they confirm the results of their predecessors. "The conclusion seems inevitable that diamonds have not yet been produced in the laboratory, and that investigators have been misled into regarding as diamonds various transparent singly-refracting minerals which happen to be very resistant to chemical reagents." G. F. S.

A New Radiation. C. V. Raman. (*Indian J. Physics*, Vol. 2, Pt. 3.) This address was delivered to the South Indian Science Association on March 16, 1928 at Bangalore.

Atoms and molecules may be made to emit light by heating or by bombarding with streams of electrons. Such radiation is designated primary. When under the influence of strong illumination substances are made to emit radiation it is called secondary. The light given out by fluorescent materials is of this kind. In the same category belongs scattered light which gives the blue color to the sky and to the deep sea and causes the opalescent effect in large bodies of clear ice. This scattering effect occurs in solids, liquids and gases.

During the past seven years much work has been done in Prof. Raman's laboratory in Calcutta upon the scattering of light by transparent media. He says "One important outcome of our researches has been to show that while light-scattering is in one sense a molecular phenomenon, in another sense it is a bulk-effect having a thermal origin. It is the thermal agitation of the molecules which causes them to be distributed and oriented in space with incomplete regularity, and it is the local fluctuations in the medium thus arising which give rise to optical heterogeneity and consequent diffusion of light. The subject of light-scattering is thus a meeting ground for thermodynamics, molecular physics and the wave-theory of radiation." The investigations of Ramanathan, Krishnan and Venkateswaren brought to light some significant polarization effects which led early in 1928 to a very important observation made by Raman and Krishnan. They had at their disposal a strong beam of sunlight concentrated by using a seven-inch telescope objective with a short focus lens. The resulting beam traversed a blue-violet filter and then entered a bulb containing a liquid that had been distilled in vacuo. They had a green glass filter that transmitted none of the light that came through the other filter. When both were placed in the path of the incident beam no light came from the liquid because no light reached it. If, however, the

first filter was in the incident beam while the other was held between the liquid and the observer the opalescent path of the beam in the liquid remained still visible, though it was not as bright as it appeared upon removing the filter. Eighty liquids were examined and all manifested this effect. (The speaker demonstrated the phenomenon to his audience with toluene.) It is true that the newly observed effect resembles fluorescence but it differs from it in this that the light from the liquid is distinctly polarized. Ice, amorphous solids, organic vapors, CO_2 and N_2O, all display the effect.

The spectrum of the light originating in the liquid benzene was studied. Light from a quartz mercury lamp was sent through a filter that cut out all wave-lengths longer than the indigo line 4358 A.U. The spectrum of the liquid excited by this radiation of short wave-length was photographed as well as that of the incident radiation. The spectrogram from the liquid shows several sharp lines not found in the light before it reached the benzene. "It is thus clear that each line in the incident spectrum gives rise to at least two lines in the scattered spectrum, one in the original or unmodified position, and a second in a position of longer wave-length. There is thus a striking analogy with the Compton effect in the X-ray region. The most pressing question is, how is the modified scattered radiation, as we may call it, generated by the molecules of the liquid? As a tentative explanation we may adopt the language of the quantum theory, and say that the incident quantum of radiation is partially absorbed by the molecule, and that the unabsorbed part is scattered."

G. F. S.

Optical Exhibition, Washington. The Optical Society of America and the Bureau of Standards will conduct an exhibition of optical instruments and optical products in the buildings of the Bureau on October 31, November 1, 2, 3. It will be open daily during the sessions of this annual meeting of the Optical Society and during one evening session.

New instruments and apparatus of especial design will be included. All American-made instruments or products in which the application of optical principles is an important part in design, construction or use, are eligible. The following partial classification will indicate the character and scope of the exhibition: optical and colored glasses, fused silica, optical components, spectacle lenses, ophthalmic instruments, binoculars, microscopes, photographic apparatus, colored photographic processes, motion picture apparatus, astronomical instruments, interferometers, spectral apparatus, metrological instruments, surveying and nautical instruments,

search-lights, telescopic gunsights, photometric apparatus, optical pyrometers, colorimetric instruments, vacuum discharge tubes, special systems of illumination, etc.

Intending exhibitors should communicate with Mr. I. C. Gardner, Chairman, Committee on Optical Instrument Exhibit, Bureau of Standards, Washington, D. C.

World Congress on Illumination. Immediately following the meeting of the Illuminating Engineering Society which will open in Toronto on September 17 next, there will be held at Saranac Inn, New York, the first international congress on illumination. Foreign delegates to this congress will meet in New York about September 5.

Members of the Illuminating Engineering Society will have an opportunity to accompany the foreign visitors on their tour of inspection of lighting installations, laboratories and manufacturing establishments devoted to lighting. The meetings of the Congress will be held on September 22 to 28 inclusive and papers will be presented by leading authorities on scientific and practical subjects of outstanding interest.

International symposia on residence lighting, show-window lighting, lighting for aviation and the status of lighting education have been arranged.

Open committee meetings for the discussion of topics assigned to international committees have aroused the greatest interest throughout the lighting industry. Sessions are scheduled to be held under the auspices of various International technical committees covering Automobile Headlighting, directed by Dr. Clayton H. Sharp, of the United States Committee; Daylight Illumination, by the British Committee; Factory and School Lighting, by U. S. National Committee; Research on Glare, under the secretariat of the Italian National Committee; and Street Lighting, directed by W. Wissman, of Germany.

The International Commission on Illumination, which was founded in 1900 as the International Photometric Commission, has been the international medium for conference and standardization in illumination matters, and has been responsible for many important international understandings.

Fixed Nitrogen in Competition with Chilian Nitrate. (Press Service U. S. Department of Agriculture.) For many years the extensive and unique deposits of sodium nitrate in Chile have enabled that country to determine the price of the material. The other natural sources of nitrogen compounds have not been able to compete. The progress of methods for the fixation of atmospheric

nitrogen now threatens the Chilian monopoly, and may have a serious effect on the revenues of the government which has relied very largely upon taxes on the product. The first efforts at nitrogen fixation were with the arc; later the cyanamide process was developed. Both these however, require large electrical power and consequently are not economically operated except where natural conditions such as water power are favorable.

Recently the development of the direct synthetic process for making ammonia by combination of nitrogen and hydrogen under the influence of a catalyst has reached such a point that it is now clearly evident that the Chilian monopoly will before long be seriously challenged, and the major nations will be entirely self-reliant for their supplies of nitrogen compounds. Germany was the first to operate this method on a very large scale but other nations are now entering the field actively. It is gratifying to note that United States has several large plants under operation by private companies. H. L.

Sodium Alum. Sodium alum (the double sulphate of sodium and aluminium) was discovered by Gehlen in 1815; Zellner, in 1816, published the results of his elaborate study of this double salt; he determined its percentage composition, and gave it its name, Natrumalaun or sodium alum. Henry Leffmann and Lester W. Strock (*Bull. Wagner Free Inst. Science*, 1928, **3**, 19–22) have studied this alum anew. Crystals are not readily obtained on cooling the boiling saturated, aqueous solution, but deposit on evaporation at a moderate temperature, or on spontaneous evaporation at room temperature. The crystals are isotropic to polarized light, clear, and brilliant. Octahedra have been obtained measuring approximately one centimeter on the edge. The usual form is the octahedron truncated by the cube. Cubes have been obtained, also a monoclinic crystalline form. The crystals effloresce readily; exposure to the air for several minutes suffices to develop a white, powdery material on the edges of the crystals. The paper is illustrated with a picture of the crystals. J. S. H.

Vitamin B. HERBERT M. EVANS AND GEORGE O. BURR of the University of California (*Jour. Biol. Chem.*, 1928, **77**, 231–240) find that the vitamin hitherto designated as water-soluble B actually consists of two distinct vitamins, one of which is antineuritic while the other is purely a promoter of growth. They used rats as experimental animals. The dilute alcoholic extract of white rice polishings, known as tikitiki, is almost lacking in the growth-promoting vitamin, but is rich in the antinuritic vitamin which

prevents beriberi in man and polyneuritis in animals. Commercial casein and commercial corn-starch lack the antineuritic vitamin, but contain the growth-promoting vitamin. Both vitamins are present in yeast. They are now designated, respectively, as antineuritic vitamin B, and purely growth-promoting vitamin B.

J. H. S.

Flavor and Odor of Milk. C. J. BABCOCK (Certified Milk Conferences, 1927, 122–126) has studied the influence of various feeds upon the flavor and odor of milk. In one series of experiments, the feed was given to the cows one hour prior to milking. Green alfalfa, cabbage, turnips, rape, kale, and silage made from corn, alfalfa, sweet clover, and soy beans exerted a marked influence on both the flavor and the odor of the milk. Green rye, cowpeas, Irish potatoes, carrots, and dried beet pulp exerted a slight influence, while green corn, oats, peas, soy beans, pumpkins, and sugar beets had no influence. The influence of large amounts of cabbage was apparent twelve hours after feeding, that of the bitter weed, *Helinium tenuifolium*, for twenty-seven hours after feeding. As a rule, the objectionable odor and flavor were more pronounced in the cream than in the skimmed milk; however, in the case of bitter weed, they were more apparent in the skimmed milk; they were usually removed to a marked extent by aëration.

The influence of garlic was studied in some detail. The garlic odor and flavor appeared in the milk in one minute after cows had eaten one-half pound of garlic tops, was still present at the end of four hours, and had almost disappeared at the end of seven hours. They were present in milk taken two minutes after cows had been made to inhale the odor of garlic for ten minutes, but had practically disappeared when milk was drawn an hour and a half after the inhalation. Cows were fed two pounds of garlic tops; their blood had a perceptible garlic odor at the end of thirty minutes, and a still more marked garlic odor at the end of forty-five minutes.

The entire group of experiments demonstrated that the odor and flavor of the feed may be absorbed from either the lungs or the digestive tract, pass into the blood, and be imparted to the milk.

J. S. H.

Quality of the Surface Waters of New Jersey. According to W. D. COLLINS AND C. S. HOWARD (U. S. Geol. Survey Water Supply Paper 596E, 89–119, 1927) the surface waters of New Jersey are fairly clear, not highly colored, and of a low mineral content. The predominating constituents are calcium, magnesium, and bicarbonate ions, with lesser amounts of sodium, chloride, and

sulphate ions. The chloride and sulphate content may be increased by sewage and industrial wastes. The waters in the southern part of the state are softer but more highly colored than those in the northern part of the state. The surface waters are one of the most valuable natural resources of the state. Results are given of the analyses of 121 samples of surface waters; the analyses deal more especially with mineral constituents; however the total dissolved solids, chlorides, and nitrates also have sanitary significance.

J. S. H.

Fossils of the Pocono Formation. GEORGE H. GIRTY (U. S. Geol. Survey, Professional Paper 150E, 111–127, 1928) has examined and described the fauna of the Pocono formation in the Broad Top Coal Field of Pennsylvania. The fossils came from four localities, and included twenty species of marine invertebrates; brachiopods predominated. Each genus is represented by but a single species. While of Carboniferous age, yet this formation lacks certain highly characteristic genera of that age. J. S. H.

Preparation of Reagent Alcohol. SOL KICZALES (*Ind. Eng. Chem.*, 1928, **20**, 493) has devised the following procedure for the preparation of aldehyde-free reagent alcohol. To each liter of alcohol are added, first a solution of 2.5 or 3 grams of lead acetate in 5 cc. of distilled water, then a solution of 5 grams of potassium hydroxide in 25 cc. of warm alcohol. The solution of lead acetate is added with thorough mixing. The solution of potassium hydroxide is added slowly without stirring; one hour later the liquid is thoroughly mixed, then permitted to stand over night. A precipitate forms, which is an addition product of lead oxide with the aldehyde originally present in the alcohol. The precipitate is removed by filtration; and the filtrate is distilled to obtain aldehyde-free alcohol, which is used in the preparation of alcoholic potash reagent. This procedure is more efficient and more economical than that based on the use of silver oxide. J. S. H.

New Reagent for Potassium. RUFUS D. REED AND JAMES R. WITHROW (*Jour. Am. Chem. Soc.*, 1928, **50**, 1515–1522) recommend the use of zirconium sulphate as a reagent for the detection of potassium. The aqueous solution of zirconium sulphate was approximately saturated at room temperature; it was prepared by stirring the powdered salt with distilled water for four hours, standing over night, and filtering, and contained 20.96 grams of the salt per 100 cc. In order to detect potassium, a definite volume of the unknown solution was mixed with an equal volume of the

zirconium sulphate solution. If a precipitate of potassium zirconium sulphate did not form at room temperature, the solution was cooled in ice water. With small amounts of potassium, a blank experiment was also made, using zirconium sulphate plus either water (in the absence of sodium in the test proper) or sodium sulphate solution (when sodium was present in the test proper). This procedure was sufficiently delicate to detect 0.5 milligram of potassium present as the 0.0068 molar solution of potassium sulphate, and to detect 1.76 milligrams of potassium in the presence of sodium. Dilution of the zirconium sulphate solution to one-half strength had practically no influence upon its sensitiveness for potassium in the absence of sodium, and increased its sensitiveness to 0.7 milligram of potassium in the presence of sodium. Large amounts of sodium sulphate retarded this reaction for potassium in concentrated solutions, but had little or no influence when the potassium was present in small amounts. J. S. H.

Electro-Deposited Copper. ARTHUR KENNETH GRAHAM (Thesis, University of Pennsylvania, 1927, 1–21) has studied the influence of various variable factors upon the structure of electro-deposited copper, when the electrolyte is an acid solution of cupric sulphate. The base metal was found to influence the structure of the deposited copper. J. S. H.

Biological Test of Glass Substitutes. R. L. COCHRAN AND H. A. BITTENBENDER (Iowa State Coll. Agric. and Mechanic Arts, Agric. Exp. Station Bull. 246, 168–184, 1928) have tested five commercial glass substitutes for their permeability to the biologically active ultra-violet rays. Growing chickens served as experimental animals. The glass substitutes were used as the top and front of boxes in which the chickens were exposed to the sunshine. Prevention of the condition known as leg weakness was a measure of the permeability of the substitute to the beneficial ultra violet rays. Physical laboratory tests showed that the substitutes transmitted from 4.0 to 30.7 per cent. of the ultra violet rays of sunlight, and from 0.0 to 26.1 per cent. of the ultra violet rays of the quartz mercury vapor lamp. Four of the substitutes transmitted sufficient of the active rays to prevent the development of leg weakness; the fifth substitute did not present this condition, the physical tests showed that this substitute transmitted less ultra violet of solar origin than did window glass. When the ration was well balanced with respect to its mineral constituents, leg weakness was prevented by a small amount of ultra violet light, *e.g.*, an average daily exposure to sunlight for 55 minutes during the winter months, provided

the glass substitutes transmitted at least 12 per cent. of the beneficial rays. Lack of these rays could be compensated by the addition of 2 per cent. of cod liver oil to the ration. The recommendation is made that, whenever glass substitutes are used, they always be placed in a vertical position. J. S. H.

Radio Communication on Moving Trains.—The utility of radio in maintaining communication for signaling and other purposes between the engine and caboose of long freight trains was submitted to the test of a practical trial, under actual working conditions, by the Pennsylvania Railroad. For this purpose a demonstration run with an experimentally radio-equipped train was made on June 26, from Altoona, Pa., to Pittsburgh, Pa.

The test was witnessed and the results recorded by officers representing various departments of the Pennsylvania Railroad, and the Westinghouse Electric and Manufacturing Company, by which the signal equipment was made. There were also present officers of other trunk line railroads.

The apparatus required for the tests was installed in a Pennsylvania Railroad Class I–1s locomotive, such as is used in the heaviest freight service, which headed the train, and in an all-steel cabin car which was at its rear.

The radio system which was used was devised to maintain both telephonic communication and code signaling. Transmitters and receivers, with loud speakers, are provided in both the locomotive and caboose. The effective range of the system much exceeds the length of any freight trains ever operated.

The Horse Shoe Curve territory of the Alleghenies was chosen for the experiment because the run provided a number of situations in which the use of radio communication between the engine and caboose should prove most effective.

Among the advantages of radio signaling is the fact that after the flagman has been dropped back and is recalled, the train may be started instantly when he reaches the caboose. When the train pulls into a siding the engineman may be notified as soon as the caboose has cleared the switch. If a standing train has to be parted at a grade crossing to allow highway traffic to pass, the engineman may be advised by radio to back up so as to permit uncoupling at the right point, then to proceed, and then to stop. At any time a member of the crew at the rear of the train can immediately notify the engineman should any trouble or difficulty be observed.

It is expected that the results of these tests will enable the railroad officials to form a more accurate opinion than has been heretofore possible as to the value of radio communication under

all conditions of service. The radio engineers who have devised the new signaling system believe that sets on passing trains should not interfere with each other, as each will operate on a wave-length of its own.

Measurement of the True Specific Heat of Nickel by a Direct Electrical Method. MISS CH. LAPP. (*Comptes Rendus*, April 23, 1928.) Measurements were made on pure nickel for temperatures ranging from − 175° to + 460°. A nickel wire is put in a furnace whose temperature is kept uniform. For a part of a minute an electric current is sent through the wire the temperature of which is thereby raised one or two degrees. The temperature is obtained from a thermoelectric couple and the time is registered by a chronograph. From the use of these data supplemented by the energy furnished by the current to the wire it is possible to compute the specific heats at different temperatures.

Temperature	−175°	+10°	339°	350°	352.2°	352.8°	353.8°	360°	460°
Specific Heat	.055	.1062	.147	.1541	.156	.1577	.1577	.1278	.1288

It will be noticed that the value decreases very suddenly from 353° to 360°. This corresponds to the change of nickel from the ferromagnetic to the paramagnetic state. From a study of the specific heats this temperature of change, the Curie point, is put at 356.1° whereas from magnetic measurements it has been located at 357.6°.

G. F. S.

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THE HEAT CAPACITIES OF ORGANIC COMPOUNDS AT LOW TEMPERATURES. I. A PRECISION CALORIMETER AND THERMOSTAT FOR LOW TEMPERATURES.

BY

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BARTOL RESEARCH FOUNDATION
Communication No. 27.

THE interest in specific heats today is due primarily to two developments in theoretical physics which took place in the first decade of the present century. One is the application of the quantum theory by Einstein and Debye [1] to the problems dealing with the thermal energy of crystals, making possible the use of specific heats for studying the motion of atoms in the crystal lattice, and the forces between them. The other is the formulation of the third law of Thermodynamics by Nernst [2] which makes specific heats of great importance in studying chemical activity. In working out the application of these principles for various substances and chemical systems the investigators in this field devoted themselves almost exclusively to the chemical elements and a few of their simpler compounds, thereby securing results which were

[1] A. Einstein, *Ann. d. Phys.* (4), **22**, 180 (1907).
P. Debye, *Ann. d. Phys.* (4), 789 (1912), vol. 39.

[2] *Nachr. kgl. Ges. Wiss. Göttingen. Math-physik. Klasse*, 1906, 1.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

an excellent confirmation of the hypotheses, but rather limited in scope.[3]

As an extension of this work the author has recently begun a survey of the specific heats of more complicated compounds, particularly the compounds of carbon. The preliminary survey which has been made indicates that the regularities of structure among these compounds constitute a unique opportunity for investigating the relation of the quantum theory to the chemical bond and the calculation of chemical activity.[4] Moreover the importance of organic chemistry to industry and medical science would itself justify any research along these lines.

However, the measurement of the specific heats of organic compounds presents certain difficulties which were not met with in the earlier work on inorganic substances. In the first place organic compounds have low heat conductivity which makes temperature measurement difficult. Secondly, many of them are corrosive so that the vessel containing them must be one which resists their chemical action. Thirdly, many of them can be obtained only in very small amounts.

The investigation described in this paper is the first step in devising apparatus suitable for making an extensive study

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[3] An account of the principal investigations in Germany can be found in the New Heat Theorem by Nernst, New York, 1927, and of work in the United States in Thermodynamics by G. N. Lewis and M. Randall, New York, 1923.

G. S. Parks and his students have made an investigation of the thermal properties of some organic compounds, especially the alcohols, from which they have drawn important deductions regarding the change of free energy in this group. See Parks, *J. A. C. S.*, **47**, 338 (1925); Parks and Kelly, *J. A. C. S.*, **47**, 2089 (1925); Parks and Nelson, *Jour. Phys. Chem.*, **32**, 61 (1928).

[4] Experimental investigations:

"The Heat Capacities and Heats of Crystallization of some Isomeric Aromatic Compounds," D. H. Andrews, George Lynn and John Johnston, *Jour. Am. Chem. Soc.*, **48**, 1274 (1926).

"The Specific Heats of Some Isomers of the Type Ortho, Meta and Para C_6H_4XY from 110° to 340° K.," Donald H. Andrews, *Jour. Am. Chem. Soc.*, **48**, 1287 (1926).

Theoretical papers:

"The Distribution of Thermal Energy in Organic Molecules," Donald H. Andrews, *Proc. Roy. Acad. Sci. Amsterdam*, **29**, 744 (1926).

"Fundamental Frequencies, Interatomic Forces and Molecular Properties," John R. Bates and Donald H. Andrews, *Proc. Nat. Acad. Sci. U. S. A.*, **14**, 124–130 (1928).

of these compounds. The calorimeter is built especially for the purpose of measuring the specific heats of such substances from about − 200° C. to room temperature with as great precision as possible. Special attention has been paid to overcoming the difficulties just mentioned, as well as sources of error present in all measurements of this type. As a test of the apparatus the specific heats of some long chain carbon compounds have been measured. Using as standards some substances as these with carefully measured heat capacities, it is planned to construct other calorimeters, much more rapid and easy to operate, with which the specific heats of a large number of other compounds can be measured by comparison with these standards.

THE APPARATUS.

The calorimeter is of the type first devised by Nernst [5] and his colleagues and improved by Gibson and Giauque [6] and by Parks.[7] It consists of a small can of gold containing the substance of which the heat capacity is to be measured. This can hangs in a vacuum chamber in order to insulate it thermally from its surroundings. A known quantity of electrical energy is passed into a heating coil in the calorimeter and the rise in temperature of calorimeter and contents observed. From this the heat capacity is calculated. The calorimeter together with the auxiliary apparatus, such as the thermostat for calibrating thermocouples are described in the following sections. The manipulation and arrangement of the various parts of the apparatus differed at times from that indicated here which represents what was found to be the most satisfactory arrangement.

The Steel Vacuum Jacket: The vessel in which the vacuum is maintained both for the calorimetric experiments and for the calibration thermostat, consists of a steel cylinder (*B*) with bottom welded in, as shown in Figs. 1 and 2. The upper edge of the inside of the cylinder is rounded off and carefully polished. This presses against a similar rounded

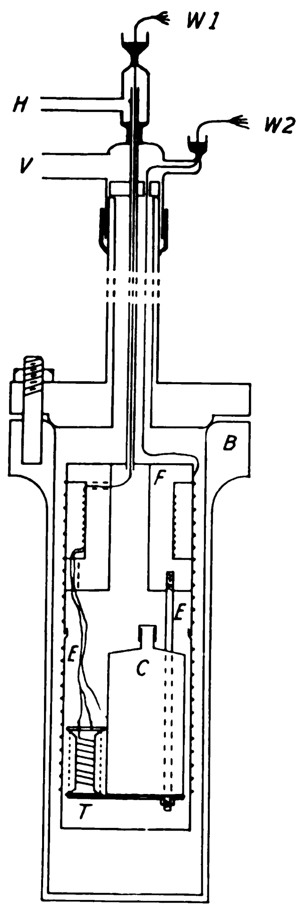
[5] Nernst, *Jour. de Physique* (4), 9, 1910; Nernst, Koref and Lindemann, *Sitzungsber. Berl. Akad.*, 1, 247 (1910). Nernst, *Ann. d. Phys.*, 4, 36, 395 (1911).

[6] Gibson and Giauque, *Jour. Am. Chem. Soc.*, 45, 93 (1923).

[7] Parks, loc. cit.

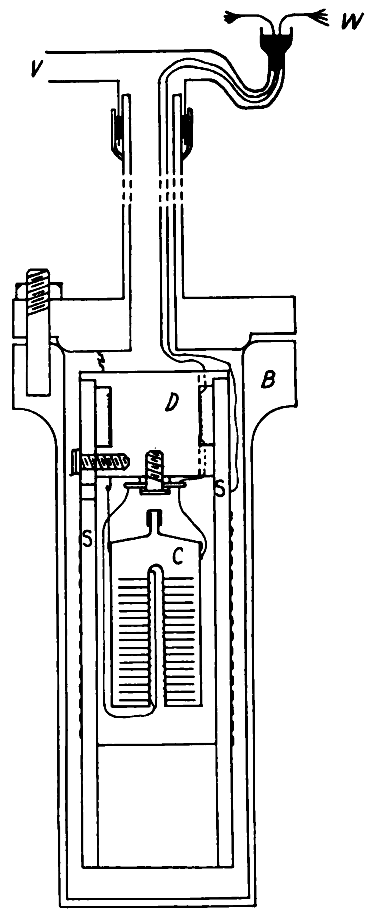
surface on the bottom of the steel cover, pressure being produced by means of twelve bolts, one of which is shown on the left side of the drawing. This proves to be a very

FIG. 1.



The Low Temperature Thermostat.

FIG. 2.



The Calorimeter, with shield and vacuum chamber.

satisfactory vacuum joint, if care is taken to keep the surface well oiled in order to prevent rust. Into the cover there is welded a steel pipe 2.5 ft. long, which terminates at the upper end in a bayonet joint. The glass tubing of the vacuum system (*v*) fits into the cavity of the joint which is made

vacuum tight with DeKhotinsky cement. The wires for heating and temperature measurements are brought out through a side arm likewise sealed with DeKhotinsky cement. A mercury diffusion pump backed with a Nelson oil pump is used to maintain the vacuum and with this system it is possible to reduce the pressure to about 10^{-5} mm.

The Low Temperature Thermostat: This was designed to provide a chamber for comparing the different temperature measuring devices. The apparatus which has been used in the past for securing constant temperature from 100° to 300° K. has nearly always employed baths of some inflammable liquid such as pentane, which is not very desirable in the neighborhood of liquid air. The apparatus described here has therefore advantage over the previous types, in this respect and in respect to the constancy of temperature.

As shown in Fig. 1, it consists of two cylinders of spun copper each closed at one end, and the open ends fitting together in a slip joint, shown just below *E*, which is made vacuum tight with low melting (60° C.) solder. This cylindrical vessel is suspended on a seamless steel tube which is hard soldered into the upper end. The tube goes up the steel pipe of the vacuum vessel and is itself supported from the top of this pipe by an adjustable collar. It passes out of the vacuum system through a DeKhotinsky cement seal (shown in heavy black) and terminates in the chamber connected to a hydrogen supply (*H*).

In the upper end of the spun copper cylinder (*E*), there is wedged a heavy cone of copper (*F*). From this is suspended by means of a small brass rod, a copper platform upon which rest the calorimeter (*C*) and platinum resistance thermometer (*T*).

The wires ($W1$) to the thermocouples on the calorimeter and to the resistance thermometer come through DeKhotinsky cement into the hydrogen chambers and then down the steel tubing into *E*, where they are wound around the block *F* several times to prevent heat leaking past, good contact being made with bakelite varnish. The wires then pass down to the resistance thermometer and calorimeter.

On the outside of the cylinder *E* there is wound a heating coil of No. 30 Constantan wire, the leads of which pass up the steel pipe and out through DeKhotinsky cement, as ($W2$).

A copper-constantan thermocouple on the outside of E also comes out along with the heating wires. It has the customary ice junction and is arranged so that its e.m.f. can be read on a potentiometer or balanced against the e.m.f. from a large capacity storage battery. This latter can be regulated at any value from 0 to 6,000 micro volts so that it will just balance the e.m.f. of the thermocouple when the latter is at temperatures from $-180°$ to $50°$ C. There is a sensitive Leeds and Northrup No. 2285 mirror galvanometer in series with these so that when the e.m.f.'s do not balance a beam of light is displaced. A photoelectric cell is so arranged that a movement of the beam of light activates it, and charges the grid of a three-electrode vacuum tube, which in turn operates a relay controlling the heating current through the wires wound on E.

The operation of the thermostat is as follows: With both the vacuum system and thermostat, filled with hydrogen through V and H respectively, the steel jacket B is immersed in liquid air and cooled to the desired temperature. Then the vacuum chamber is evacuated through V, and an appropriate cooling bath maintained around B. The heating current through E is then so regulated that the thermocouple on the outside of E reads the desired temperature. Its e.m.f. is then balanced against the constant e.m.f. for the storage battery, and the galvanometer so adjusted that when the temperature falls, the photoelectric cell-relay device increases the heating current about 5 per cent., until the temperature goes above the desired temperature when the operation is reversed. With this arrangement the temperature can be kept constant to $0.01°$ C. at any point of the range $-180°$ to $50°$ C. The thermocouples inside the hydrogen chamber where the calorimeter and resistance thermometer are placed indicate a uniformity of temperature to $0.01°$ C. also. This apparatus thus provides an accurate and easily adjustable thermostat over the low temperature range where the use of constant temperature baths is difficult and dangerous. The results secured with it, in comparing the constantan thermocouple and platinum resistance thermometer are described in a later section.

The Calorimeter Shield: The problem of minimizing the

error due to heat leaks from the calorimeter to its surroundings has been met in this apparatus by surrounding the calorimeter with a cylindrical shield of heavy copper tubing, shown in Fig. 2 as (*S*). It is fitted at each end with two heavy copper blocks which provide extra heat capacity. The upper block marked (*D*) is supported from the steel cover of the vacuum jacket by loops of piano wire and in turn supports the shield by means of four copper screws, one of which is shown at the lower left hand corner of the block. This block (*D*) is also cut to provide a ring-shaped cavity between it and the shield (*S*). In this cavity are wound the thermocouple and heating wires for the calorimeter, good contact being made with bakelite varnish. The wires pass out through a hold in the lower side of the block to a hard rubber plate with a ring of holes, held in place on the lower face of the block by a screw. This acts as a distributor and from it the wires are led to the calorimeter.

On the outside of the shield (*S*) there is wound a 50 ohm heating coil of nicrome ribbon. During measurements a current is passed through this, of the appropriate strength to keep the whole shield within one or two degrees of the temperature of the calorimeter. This reduces the heat leak by conduction along the wires, and by radiation and conduction through the residual gas in the system.

The calorimeter itself is suspended from the block (*D*) by means of silk threads. It is a vessel of 18 karat gold, weighs about 250 grams, has a volume of about 100 cc. and a heat capacity of about ten calories per degree. At the top there is a small copper tube through which it is filled. This tube is closed after filling with a small spun copper cap, made vacuum tight with low melting (60° C.) solder. At the bottom of the calorimeter there is a reëntrant tube or well which goes nearly to the top. This tube supports through the center a number of discs of gold, shown in the cross-section drawing as straight lines. These discs distribute the heat from the heating coil in the well throughout the material in the vessel.

THE HEATING-TEMPERATURE MEASURING SYSTEM.

The heating coil for the calorimeter is made of a piece of No. 30 constantan wire bifilarly wound in a spiral. It was

slipped in the well, from a glass rod, and bakelited to the wall, being held in contact by its own tension. From the end of the loop at the innermost part of the well, there is a No. 36 copper wire attached. This, together with one of the ends of the constantan, is brought out of the apparatus and thus serves as a thermocouple for reading the temperature inside the calorimeter. The heating current is brought in through two pieces of No. 26 copper wire attached to the constantan wires at the mouth of the well. The drop in potential across the heating coil is read by means of two wires attached to the No. 26 wires at the distributor plate on the bottom of the block *D*.

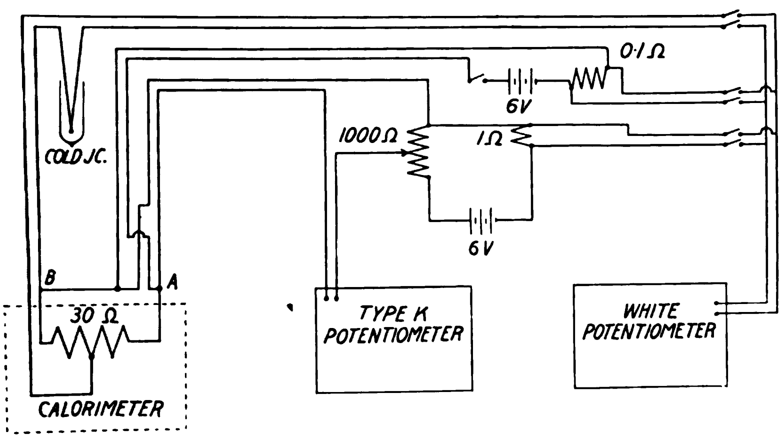
These connections are illustrated diagrammatically in Fig. 3. The No. 30 constantan wire which serves as a heating coil and thermocouple extends from *A* through the 30 ohm coil, through *B* where the lead for the heating current is taken off, to the cold junction. It is a piece of tested and calibrated wire as explained in the section on calibration.

The e.m.f. of the thermocouple is read by means of a White potentiometer made by the Leeds and Northrup Co. The most sensitive type of galvanometer was used with the scale at a distance of fifteen feet so that an absolute precision of 0.1 microvolts was secured with a sensitivity of 0.03 microvolts. The greatest care was exercised in preparing the ice in the cold junction; it was ground to mush in a porcelain mortar kept exclusively for the purpose and the optimum ratio of ice and water was maintained at all times.

The energy input in heating the calorimeter is determined by measuring the current flowing and the voltage drop across the heating coil. There is a 0.1 ohm coil, Leeds and Northrup Co., calibrated by the Bureau of Standards, placed in series with the heating coil; it is shown in the upper right hand corner of Fig. 3. The potential drop across this coil during heating is measured by means of the White potentiometer with a precision easily one part in 10,000. The potential drop across the heating coil is measured indirectly, as it is too large (six volts) to read precisely on a voltmeter or potentiometer. A six-volt battery, kept at constant temperature, sends a current through standard resistances of 1,000 ohms and one ohm, in series. The current is constant over a ten-

minute interval to one part in 10,000. This gives, for example, an e.m.f. across the 1,000 ohm coil of about 5.995 volts which is opposed to the 6 volt drop from the heating coil; the e.m.f. of .005 volt from the one ohm coil is measured on the White potentiometer, permitting an exact calculation of the larger voltage. Then during heating the difference

FIG. 3.



The heating and temperature measuring circuits.

between the potential drop across the heating coil and the above opposing e.m.f. is measured with a Leeds and Northrup Type K potentiometer. In this way the energy put into the calorimeter can be measured to one part in 5,000. This is greater precision than is necessary at present, in view of some of the uncertainties in temperature measurement; but when one wishes an accuracy greater than one part in 200, obtainable with good voltmeters, it is necessary to use the potentiometer method, and therefore it was thought well to get all the precision which could be had without undue effort.

The Timing Device: Since the energy input equals voltage × current × time, it is necessary to know the time during which the current is passed very accurately. For this reason the current is controlled by an automatic switch, which consists of a drum of hard rubber driven directly by the "minute" shaft of a Warren synchronous clock motor so

that it makes one revolution per minute. On the drum there is cut a spiral groove in which a contact point rests. There are also contacts carefully set into the groove so that when the drum turns, pulling the contacts past the point two impulses are sent out, one exactly three minutes after the other. The exact timing of the rotation of the drum is accomplished by the frequency of the current sent into the motor. This is the standard 60 cycle Philadelphia city lighting power, the frequency of which is regulated by master clocks so that the error in three minutes is never greater than a single cycle or 1/60 second, and is probably much less.

The impulses from this device operate a polarized relay, the first turning the heating current on, and the second turning it off, since a reversing switch is thrown by the observer in between. There is of course, some slight error at the beginning of each admission of current due to lag in establishing constant e.m.f. but accurate voltmeters in the circuit indicate it to be less than ten per cent. over a period of one second, corresponding to one part in 1,800. This error is further diminished by having the relay merely switch the current from an outside coil of the same resistance as the calorimeter heating coil, into the calorimeter itself.

The Method of Measuring Heat Capacity: The apparatus is assembled as shown in Fig. 2. With hydrogen in the vacuum chamber, the steel vacuum jacket (B) is immersed in liquid air until all parts of the apparatus are approximately at liquid air temperature, roughly $-180°$ C. Then the hydrogen is pumped out and a vacuum of about 10^{-5} mm. of mercury produced within the jacket. The shield (S) and the calorimeter (C) are then brought to within about 0.2° of the same temperature, and since the shield is of such large heat capacity that its temperature will remain essentially constant, even though external conditions vary, the temperature of the calorimeter will remain constant, or change very slowly (0.001° per minute) and at a regular rate. This latter temperature is read over a period of about five minutes. Then the heating current is started and allowed to flow for exactly three minutes. This raises the temperature about 2°. During this interval the energy input is measured as explained above. Then readings are taken at five minute intervals

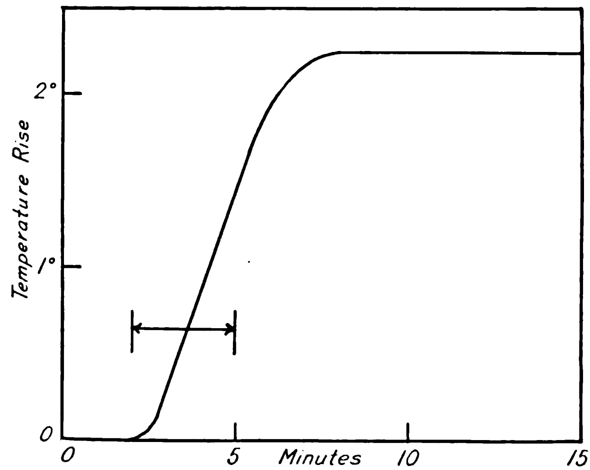
for about forty minutes. With the materials studied in these experiments it was found that temperature equilibrium was attained after about twenty minutes. The calorimeter being above the temperature of its surroundings will cool at the rate of about 0.002° per minute. The method of estimating the rise in temperature is explained in the following section.

The Measurement of Temperature: Undoubtedly the chief problem of calorimetry is the measurement of temperature and its relation to heat leaks. The customary method of measuring the temperature rise has been to use a resistance thermometer or thermocouple on the outside of the calorimeter. The rate of change of temperature with time before and after heating are measured and the two curves extrapolated to the mid point of time in the heating interval and the distance between them taken as the true rise in temperature. This involves error first, because the outside of the calorimeter has a different temperature from the inside, because of the gradient due to the cooling of the calorimeter especially after the heating interval; second, because the temperature of the surface changes during heating so that the heat loss to the surroundings is irregular. This is especially true if heating is done by means of a coil on the outside of the calorimeter.

In this apparatus this error has been minimized by placing both heating coil and thermocouple in the interior of the calorimeter. Moreover as the actual temperature of the surface of the calorimeter during heating has been observed by means of a thermocouple soldered to the gold surface, it is found that the rate of change of temperature of the calorimeter is proportional to the temperature difference between the surface and the interior wall of the shield (*S*), as Newton's law of cooling would lead us to expect. Moreover, observations of the surface temperature of the calorimeter during a number of runs have shown that the rise in temperature of the surface always follows the same general shape of curve. A typical curve is shown in Fig. 4. From this we find that the net cooling effect actually produced is the same *as if* the surface had changed temperature at its preheating rate for the first two minutes of heating, and then suddenly jumped to its post heating value and continued

along the extrapolation of the post heating curve for the last minute of the heating interval. Therefore if we extrapolate the preheating and post heating temperature curves to the time when two-thirds of the heating interval has elapsed, the difference between the two curves will be the true rise

FIG. 4.



Surface Temperature of the Calorimeter, before, during, and after heating. The heating interval is indicated by the arrows.

due to the energy passed in. This is the procedure that has been followed in calculating the results presented in the later sections.

THE CALIBRATION OF THE THERMOCOUPLES.

The temperature scale for this investigation is based upon the readings of a platinum resistance thermometer which was constructed for the purpose. The wire which conforms to the Bureau of Standards specifications, and was furnished by Baker and Co., is wound on two crossed pieces of mica in the usual fashion. These are supported between two bakelite discs—one at the top and one at the bottom—the whole being surrounded by a cylindrical cage of copper gauze. The thermometer is shown in Fig. 1; the dotted lines represent the gauze cage. In this way the hydrogen has free access to the platinum wire. Varying the current

through the thermometer fourfold changes the temperature less than 0.01° C. so that it seems certain the thermometer is at the temperature of the other objects in the thermostat.

TABLE I.

Deviations of e.m.f. of Bartol Laboratory Constantan Wire from I.C.T. values.

Temperature of Comparison.	Deviation Observed	Value Read from Smooth Curve through Deviations.
−171.54° C.	2.80° C.	2.80° C.
144.88	2.07	2.07
122.83	1.52	1.57
113.73	1.45	1.41
101.90	1.17	1.18
90.39	0.99	0.99
87.32	0.94	0.94
64.52	0.65	0.64
40.94	0.36	0.37

The fundamental constants of the thermometer were determined at the temperatures of melting ice, melting mercury, and boiling oxygen, the constancy of temperature in the last case indicating the oxygen to be about 99.95 per cent. pure. The resistance conformed to Henning's tables.[8] With the help of the thermostat shown in Fig. 3 the thermometer was compared with the copper constantan thermocouples at ten different temperatures between 0° and − 180° C. and the deviations of the thermocouple readings from Adams' table [9] were plotted and gave a smooth curve as shown in Table I. These deviations are due to the variation in composition of different lots of constantan wire. The wire used for this work, while not giving as high an e.m.f. as Adams', was very uniform in composition as shown by passing it through liquid air, and observing the resultant e.m.f. As the result of these observations it appears that the absolute values of the temperature readings are accurate to 0.02° C. and that the relative error in measuring a rise in temperature of about 2° is about 0.003° at − 180° C. and 0.001° at room temperature. In order to make use of this accuracy in measuring rise of temperature it will be necessary to get an e.m.f.-temperature table for thermo-couples extended to thousandths of a degree instead of hundredths as Adams'

[8] Landolt and Bornstein Tabellen. Fifth Edition.
[9] International Critical Tables 1926.

table. Such a table is being worked on at present and when it is finished, it is hoped that the full accuracy of the calorimeter will be available.

TABLE II.

Heat Capacity of the Calorimeter.

Mean Temperature.	Heat Capacity Calories per Degree.
−154.5° C.	10.89
−149.3	11.00
−145.1	11.04
−139.1	11.23
− 98.8	11.80
− 62.9	12.12
− 45.5	12.40

TABLE III.

Heat Capacity of n-heptaldehyde.

$CH^3.CH_2.CH_2.CH_2.CH_2.CH_2.CHO$.

Mean Temperature.	Molal Heat Capacity Calories per Degree.	Specific Heat Calories per Degree.
−167.57° C.	29.40	0.258
−165.53	30.02	0.263
−127.00	39.30	0.344
−125.68	39.49	0.346
− 81.73	49.73	0.436
− 80.32	49.19	0.431
− 56.4 *	79.80	0.699
− 55.3 *	103.50	0.907

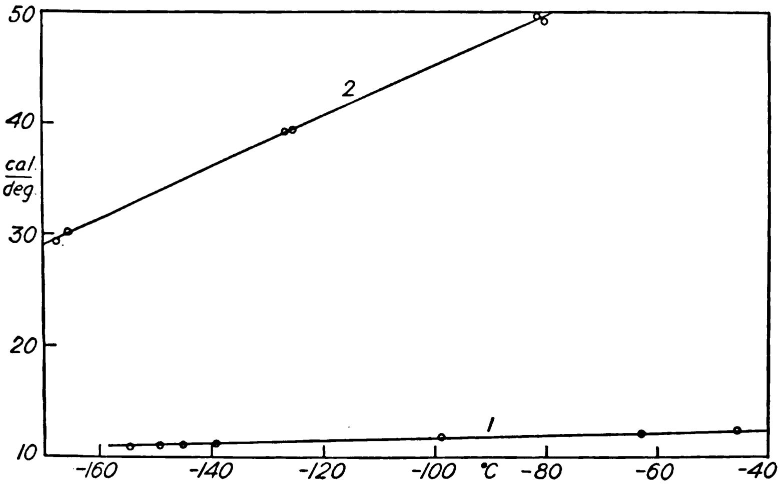
* Partial melting taking place.

Experimental Behavior: As an example of the results which can be secured with the calorimeter there are given in Tables II and III, the heat capacities for the calorimeter itself and for n-heptaldehyde. The other heat capacities measured with the calorimeter will be presented in Part II of this paper together with a discussion of their theoretical significance.

The average deviation from the best smooth curve is 0.39 per cent. in the case of heptaldehyde and 0.18 per cent. for the calorimeter itself. These errors are of the same order of magnitude as the errors in making temperature measurement a good part of which is due to the uncertainty in using the thermocouple e.m.f. tables from the International Critical Tables. The author, therefore, plans to make measurements for an e.m.f. temperature table which will be accurate to about 0.002° C., at least for measuring the

temperature rise. This will be used for calculating the other specific heat measurements.

FIG. 5.



The heat capacity (1) of the gold calorimeter, (2) of one mol of n-heptaldehyde.

Considering the accuracy with which the other factors have been measured, these measurements should serve as a good standard for further investigations when the temperature scale can be accurately established.

A Method of Measuring the Radiant Heat Emitted during Gaseous Explosions. C. H. JOHNSON. (*Phil. Mag.*, Feb., 1926.) A considerable part of the heat of combustion is radiated from flames. Infra-red waves predominate though the visible and the ultra-violet portions of the spectrum also are represented. The conditions of experiment greatly affect the percentage of the heat of combustion that escapes as radiation. For a large flame of coal-gas Callendar found the fraction to be 16 per cent., while small flames emitted only 2 or 3 per cent. Hopkinson in 1910 studied radiation during explosions and "found that the energy radiated during explosion and cooling amounted to 22 per cent. of the gross heat of combustion; only 3 per cent. appeared up to the time of attainment of maximum pressure, which must represent roughly that emitted during the period of inflammation." While subsequent investigations have confirmed the main outlines of these results there is a real need of additional information for engineering purposes and also for "physical chemistry in its endeavor to unravel the problems of mechanism of chemical reaction, and in particular of the part played by radiation from the flame front in 'activating' the unburnt gases ahead of the wave."

The author sought to isolate the radiation emitted by the wave-front from that coming out of the hot products of combustion behind it. For this purpose he used a long cylindrical bomb in which the burnt gases cool quickly and thus soon drop out of consideration as radiators. His explosive mixture consisted of carbon monoxide and oxygen in the proportions 2 : 1. The per cent. of the gross heat of combustion radiated during explosion was for the dry mixture 8.6, for the wet mixture 2.3, and for the dried gas containing 1 per cent. by volume of CCl_4, 9.5. "The effect of water, and incidentally of other catalysts, upon the emission of infra-red radiation from the wave-front in explosions of carbon monoxide and oxygen has proved to be of considerable magnitude. In particular, an additional 7 per cent. of the gross heat of combustion was radiated from a dried gas mixture in excess of that emitted in the presence of 1.9 per cent. of water-vapor."

G. F. S.

THE REFLECTION OF HYDROGEN ATOMS FROM CRYSTALS.

BY

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BARTOL RESEARCH FOUNDATION
Communication No. 28.

THE distribution in angle of molecules reflected from a surface was first investigated by R. W. Wood [1] who found that a unidirectional beam of mercury atoms was diffusely reflected from a polished glass surface. Previously in the study of the flow of gases through tubes and similar phenomena, the hypothesis of diffuse reflection had been found satisfactory in most cases for explaining the observed transfer of momentum from a gas to a surface,[2] but in a few instances it was thought that some specular reflection must have existed. More recently Ellett and Olson,[3] using the direct method of molecular beams, have shown that mercury and cadmium atoms are specularly reflected in a considerable amount from a cleavage surface of a heated crystal of rock salt.

Somewhat over a year ago the writer began a study of the reflection of atomic hydrogen from crystals. The first experiments,[4] in which a many crystal surface of ice was used, gave an indication that atoms, like electrons,[5] could be regarded as waves capable of being diffracted from a crystal grating. A continuation of the work with ice, however, revealed the fact that the hydrogen beams which were at first attributed to diffraction by the ice crystals were really of quite a different character and had to be ascribed to some irregularity in the apparatus. The actual reflection in this case was probably nothing more than diffuse. The

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[1] R. W. Wood, *Phil. Mag.*, **30**, 300 (1913).

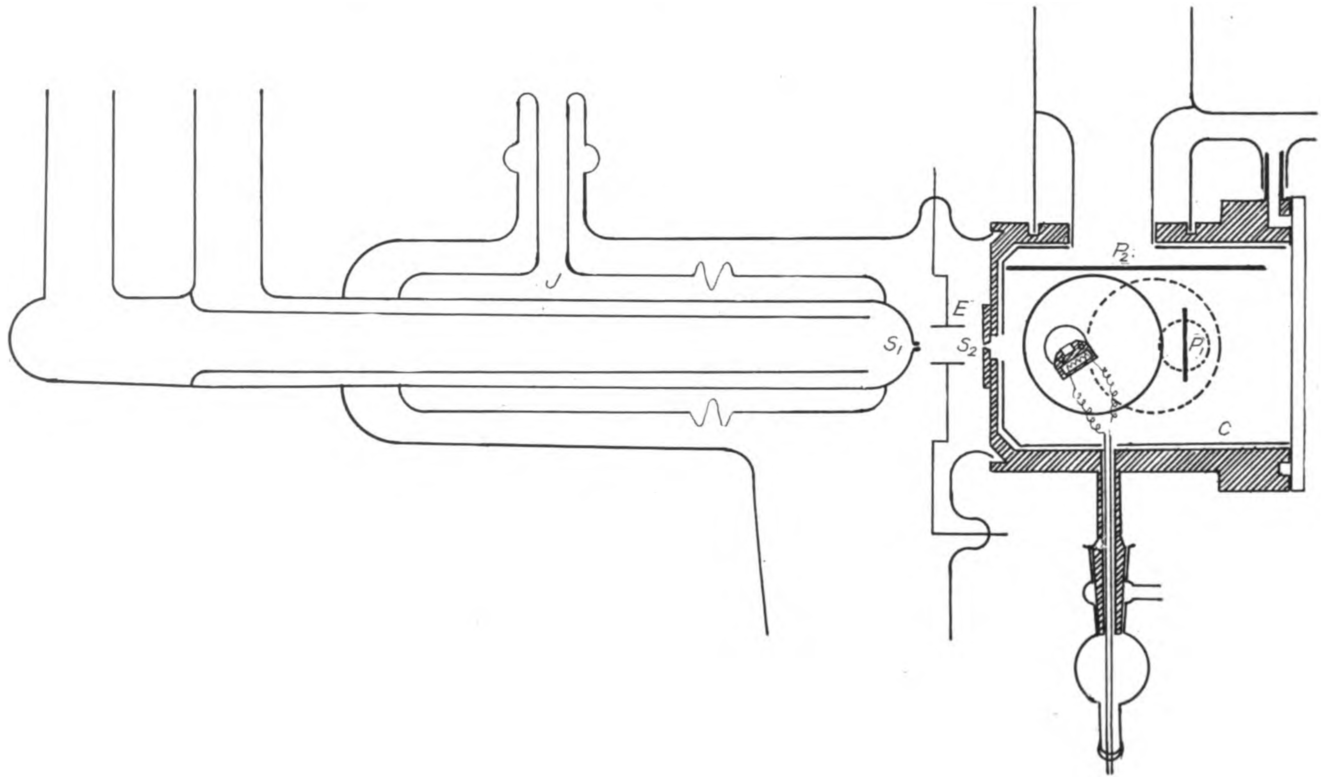
[2] A complete discussion of this evidence is contained in "The Kinetic Theory of Gases" by L. B. Loeb, p. 308.

[3] Ellett and Olson, *Phys. Rev.*, **31**, 643 (1928).

[4] T. H. Johnson, *Nature*, Aug. 6, 1927.

[5] Davisson and Germer, *Jour. of the Frank. Inst.*, April, 1928.

FIG. I.



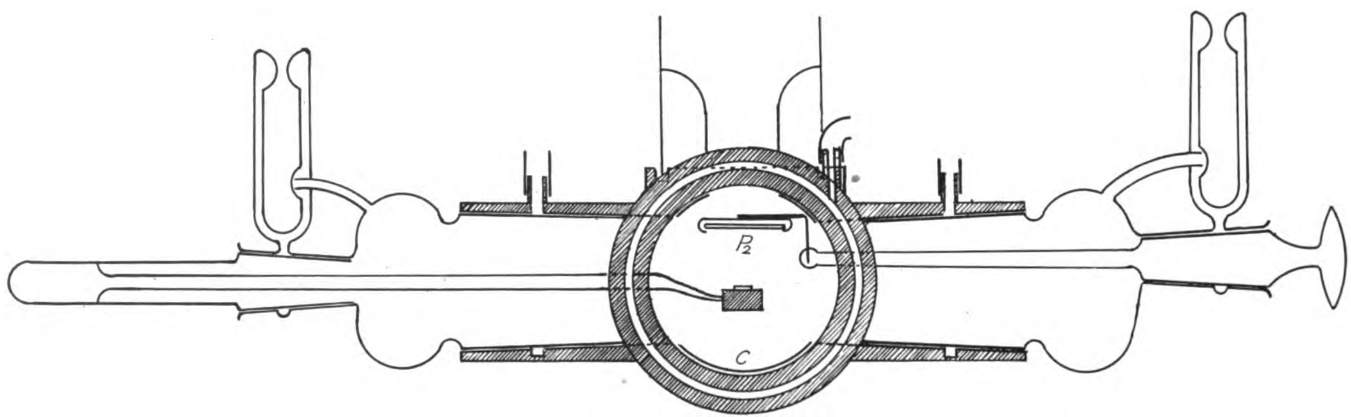
Side view of the experimental arrangements.

study of the reflection of hydrogen atoms has now been extended to certain single crystals and although the results are still only qualitative, they are in most respects definite and of considerable interest from the point of view of existing theories. The work is being continued with improved technique and it is hoped that quantitative results will be forth coming in a short time. The ultimate goal is a complete knowledge of the intensity of reflection of hydrogen atoms from crystals as a function of the direction of incidence and reflection, and a knowledge of the factors which influence this intensity.

The apparatus used in these experiments is essentially a device for producing a sharply defined ribbon-like beam of hydrogen atoms in a space which is otherwise comparatively free from gas. This beam is allowed to fall upon the reflecting surface and the intensity of reflection is measured by the use of a plate coated with a thin layer of molybdenum trioxide. The parts of the oxide surface which are exposed to the hydrogen atoms become visibly darkened by reduction to metallic molybdenum.

The source of the atomic hydrogen beam is a narrow slit S_1 in the wall of along discharge tube of the type known as a Wood tube, the central part of which is shown as a part of the experimental arrangement in Fig. 1. This part of the tube is designed to bring the discharge right up to the slit so that the hydrogen in the tube near the slit is well dissociated. Water in the jacket J prevents this portion of the discharge tube from becoming overheated. The discharge is excited by a 10,000 volt transformer which produces a current of 45 milliamps. under the pressure conditions which customarily exist in the discharge tube, i.e. about 0.15 mm. Since the gas continually escapes through S_1 it is also replenished by a variable "potentiometer" leak from an electrolytic hydrogen generator. This leak consists of three properly selected capillary tubes arranged as indicated in Fig. 3, A, B, and C being joined respectively to the hydrogen generator, the discharge tube and to an oil pump which is also a part of one of the pumping systems described below. Inside one of these capillary tubes is a magnetically operated plunger which makes possible a

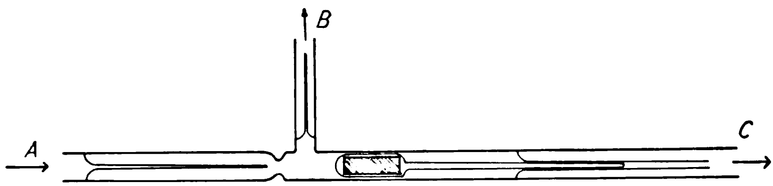
FIG. 2.



End view of experimental chamber.

variation of the resistance of this tube and consequently the pressure in the discharge. The arrangement now in use permits a variation of the discharge pressure from .03 mm. to .3 mm. and with the plunger once set, the pressure remains constant to within one or two per cent. over a period of several hours. In order that the hydrogen atoms may not recombine before leaving the discharge tube, it is necessary

FIG. 3.



Adjustable "Potentiometer" inflow leak.
A, hydrogen generator, *B*, discharge tube, *C*, oil pump.

to avoid having any metal inside the tube. Consequently the slit S_1 which is .13 mm. wide and 6 mm. long was formed in the glass itself. This was done by pressing the glass, while hot, down upon a thin strip of copper which was subsequently dissolved out with nitric and hydrofluoric acids.

Opposite and parallel to S_1 and at a distance of 1.5 cms, is a second slit S_2 having the same dimensions as S_1. This slit is in the wall of a cylindrical brass box which is waxed to the glass parts already described. In this box the reflection and the detection of the beam takes place. The region between the two slits is evacuated by means of a four stage all-steel Gaede diffusion pump operating through a short tube of large diameter and a special low resistance mercury vapor trap.[6] This pumping system is very satisfactory in reducing the pressure between the slits to the point where scattering by collisions is inappreciable and practically all of the atoms passing through S_2 come directly from S_1. In fact, the background on a plate exposed to the direct beam is of the order of one three hundredth of the intensity of the central part of the beam and falls off rapidly with the distance from the beam. The pressure between the slits as measured by a

[6] T. H. Johnson, Jour. Frank. Inst. Jan. 1928 a Mercury Vapor Trap of Low Resistance.

McCleod gauge is usually between 10^{-4} and 10^{-5} mm. To be sure that none of the effects observed are due to ions, these can be swept out by an electric field applied between the electrodes *E*. The brass box, the end of which is closed by a glass plate is evacuated by another independent pumping system consisting of a Holweck molecular pump connected by a short glass tube of large diameter and backed by an oil pump. The measured pressure in this chamber is usually less than 10^{-6} mm. The reflector and the detecting plate are mounted on compound eccentric ground glass cones (Fig. 1 and Fig. 2) which permit some adjustment both in position and inclination while the apparatus is evacuated. To prevent vapor from the stop cock grease on these cones and wax vapor from the other joints from entering the main experimental chamber all such joints are provided with guard rings connected to liquid air traps, and are greased or waxed only on the outside of these guard rings. The way in which these guard rings are arranged is clearly seen in Fig. 1 and Fig. 2. It was found that this precaution was important because a layer of grease on the interior surface of the brass box makes this surface reflecting to the atoms without their recombination and the detecting plate soon becomes generally darkened. In order to have, always, a clean interior surface a nickel cylinder *C* which is coated with platinum black is fitted into the box and this can be removed occasionally and recoated. It has been found that a fresh surface of platinum black is completely effective in recombining the atoms which strike it, and if it is protected from grease long exposures produce little general darkening of the detecting plate and a renewal of the platinum black surface is necessary only after many hours. This, however, is not true if liquid air is not applied to the traps connected to the guard rings.

Several different crystals have been tried as reflecting surfaces. In each case the crystal was mounted in a copper holder, one design of which is represented in some detail in Fig. 1. This holder has within it a resistance heating element by means of which the crystal can be raised to any desired temperature. For this reason the holder is mounted on two quartz rods which are joined by a graded seal to the glass extension of the inner ground cone. The crystal holder is

adjusted in position so that the surface of the crystal is on the axis of this cone. Thus rotation about this cone produces no displacement of the crystal with respect to the beam. The axes of the cones and the surface of the crystal are parallel to the slits. The distance from S_2 to the crystal is 1.8 cms. In some experiments a thermocouple was placed beneath the crystal but since it was impossible to know the temperature of the surface of the crystal from the reading of the thermocouple this has not been generally used and in the work which has been done the temperature was not accurately known.

The detecting plate is placed in either one of the two positions P_1 or P_2 shown in Fig. 1. These plates are of glass smoked with the white trioxide of molybdenum produced by burning thin strips of molybdenum in an oxygen-gas flame. For the formation of a uniform smoke deposit a special chimney has been found of great advantage. This chimney consists of a tube fitted with several wire gauzes. An air jet produces a thorough mixing of the smoke with the air so that above the chimney a uniform cloud of white smoke arises which deposits out on the glass plate which is held above it. The darkening of the oxide surface, due to its reduction by atomic hydrogen, can be examined either visually or it can be analysed with a densitometer. It has been found that the density as measured by the densitometer is proportional to the number of atoms which have struck the plate. There is some difficulty, however, in getting a sufficiently uniform smoke deposit to make such density measurements strictly reliable without a preliminary analysis of the unexposed plate. An accurate correlation between the position on the plate and the angle of reflection can be made by the measurement of linear distances between the plate and the crystal, and on the plate.

All of the crystals which have been investigated reflect the hydrogen atoms diffusely if the temperature of the surface is high enough. These include cleavage surfaces of calcite, sylvite, and rock salt and natural crystal faces of quartz. The intensity of the diffuse reflection depends markedly upon the temperatures of the crystal and in a way which is characteristic of the particular crystal. Sylvite must

be at a very much higher temperature than rock salt to reflect diffusely with the same intensity, whereas quartz and calcite must be at a temperature somewhere between these other two. It seems that this type of reflection is to be explained, at least in part, as an adsorption and a reevaporation of the hydrogen atoms from the surface. The mean life in the adsorbed state of an atom is to be thought of as depending upon the temperature, and as determining the amount of reevaporation in the atomic state. If the mean life is long, the probability of recombination at the surface will be high and relatively few will escape as atoms, whereas with a short mean life the probability of recombination will be small and many will escape as atoms. We naturally think of the mean life as being a function of a/kT[7] where a is the energy of adsorption of a hydrogen atom on the crystal surface, k the Boltzman constant and T the absolute temperature of the surface.

In addition to the above described diffuse reflection, a cleavage surface of rock salt also reflects specularly. With the detecting plate at a distance of 1 cm. from the crystal the specular beam can be exposed in thirty minutes. From a comparison of the intensities of the specularly reflected beam and of the primary beam it has been found that near grazing as much as 10 per cent. of the incident atoms are reflected specularly if the temperature of the crystal is just under its sublimation point, i.e. in the neighborhood of 400° C. Since the crystal is also a good reflector of the beam of light which comes from the discharge and is collimated by the slit system it has been possible to compare the direction of the specularly reflected atom beam and the specularly reflected light beam in the region near grazing. These have been found to exactly coincide. Since other substances which are good reflectors of light seem not to reflect hydrogen atoms, it is certain that the light beam has nothing to do with the observed effects.

The intensity of the specular beam from rock salt depends upon the angle of incidence and on the temperature of the crystal. An upper limit to the temperature range over which observations are possible is placed at the point where a deposit of salt begins to form over the surface of the detecting

[7] For example the theory of Frenkel Zs. für Phys. 26, 117.

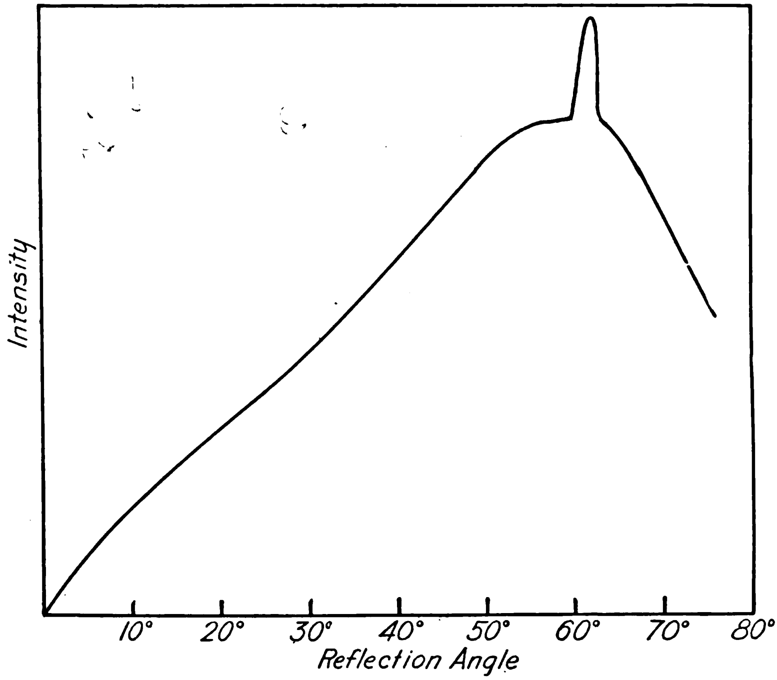
plate due to the sublimation of the crystal. This temperature is thought to be somewhere near 400° C., or perhaps a little lower. At this temperature the intensity near grazing is perhaps twice that at 30° and twenty times that at 60° from grazing. These ratios have been determined only approximately by visual comparison of double exposures. At lower temperatures the specular beams have more nearly the same intensity for all angles of incidence. Furthermore the diffuse background becomes less intense at low temperatures and it has been possible to observe a very large percentage of all of the reflected atoms in the specular beam even at angles far from grazing. At room temperature the intensities of both kinds of reflection practically vanish. This is probably due to a change of the surface due to a slow reaction between the atomic hydrogen and the salt crystal. After this reaction has been allowed to progress for some time at room temperature or just above, it is not possible to restore the reflecting power of the crystal except by heating to a temperature considerably in excess of the sublimation point. The area which has been in the hydrogen beam is then less volatile than the remainder of the surface and after a few such treatments a hump is left across the crystal. It is supposed that the reflection is extinguished by a change in the surface of the crystal primarily due to the reduction of the NaCl by the atomic hydrogen. The metallic sodium then reacts with the water vapor, which is always present in small quantities in the beam, forming a layer of NaOH over the surface.

It is perhaps an interesting observation that even after the crystal surface has been roughened by sublimation to the point where it no longer reflects light well, its reflecting power for atoms is but slightly impaired, and the specular beam still remains perfectly sharp. This must mean that the crystal surface evaporates in such a way as to leave small areas of the crystal planes intact.

A concrete idea of the relative importance of the specular and diffuse reflection is gained from the densitometer record of the reflection at 60° from grazing incidence which is reproduced in Fig. 4. The temperature of the crystal in this case was just below the sublimation point and the specular

beam was less intense compared with the background than could have been realized at lower temperatures, as has been stated above. Since no very great care has yet been taken to produce a uniform coating of oxide it is impossible to draw any very definite conclusions from the densitometer record, in regard to the distribution in angle of the diffusely reflected atoms but it seems quite certain that the directions near the specular beam are most probable.

FIG. 4.



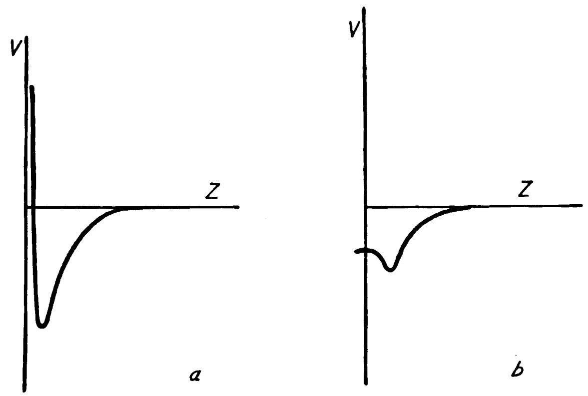
The intensity of reflection as a function of the angle of reflection as measured by the densitometer. The angle of incidence was 60° from grazing.

From the standpoint of the old mechanics the forces between the atom and the crystal may be of three types.[8] (*A*) According to the old Bohr picture, the hydrogen atom is an electric doublet. The field of the doublet produces in the dielectric crystal an induced polarisation and the inter-

[8] Lenard-Jones, *Trans. Farad. Soc.*, Feb. 1928.

action between the electric moment of the atom and this polarisation is a force of attraction. (*B*) The surface of the crystal is to be thought of as being made up of alternately positive and negative ions. The field due to these ions produces an induced polarisation of the atom and the forces due to this cause are again attractive. (*C*) Only when the atom comes very close to one of the lattice points does it experience a repulsive force and this force is ordinarily supposed to vary as about the inverse tenth power of the distance. In this regard, then, the lattice points behave very nearly as hard elastic spheres and the repulsive forces should be perfectly rough for a particle as small as the hydrogen atom. Since it is only possible to understand specular reflection of particles if there exist repulsive forces which are smooth and act normally to the surface, the old mechanics seems to be inadequate for describing this phenomenon.

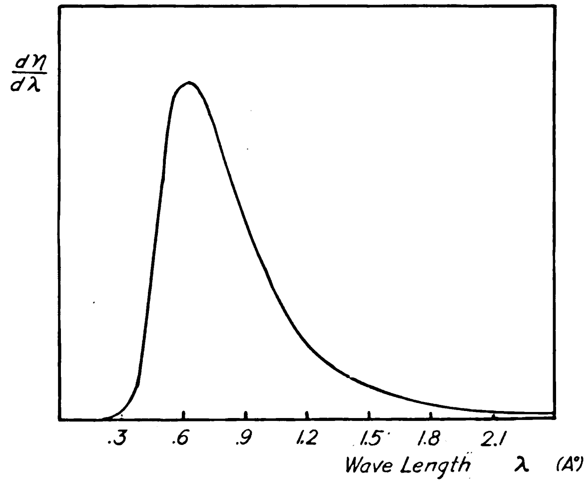
FIG. 5.



From the standpoint of the wave mechanics the atom beam is to be regarded as a set of plane waves propagated in the direction of the beam with a phase velocity $w = c^2/v$. The property of the crystal which is of interest for the reflection of waves is the potential distribution in the region of the crystal face. With this potential function known it is at least ideally possible to calculate the amplitude of the reflected wave as a function of the velocity of the incident atom and the angle of incidence and reflection. The observed

reflection may therefore be regarded as a proof of an assumed potential function. If we define the potential as the work which must be done to bring the hydrogen atom up from infinity we may expect the potential distribution along a normal drawn through one of the lattice points to be represented by a curve such as Fig. 5, *a*, and along some other intermediate normal by a curve such as Fig. 5, *b*. The wave problem with such a potential distribution is undoubtedly one of great difficulty but it is possible to predict some properties of the solution because of the close analogy with classical optics. In the first place there should be specular

FIG. 6.

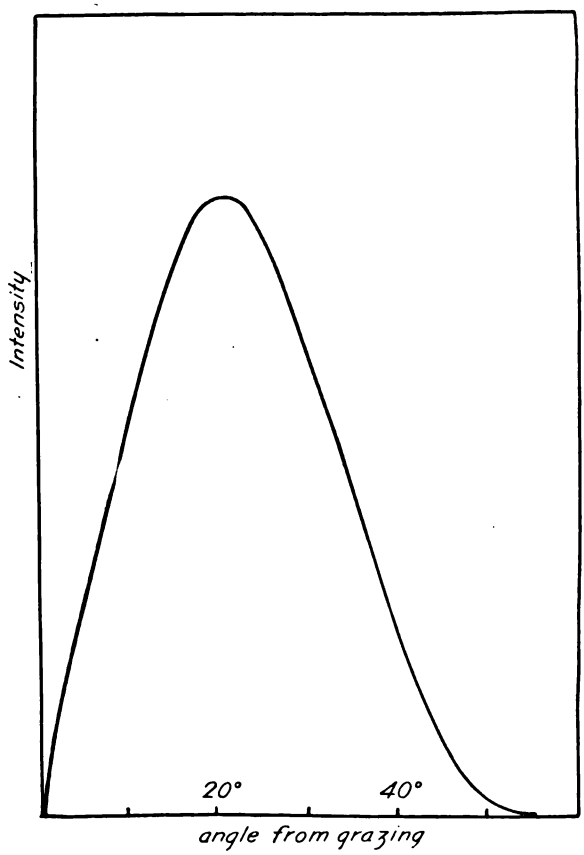


The distribution in wave-length of hydrogen atoms at 200° C. Calculated from the Maxwellian velocity distribution.

reflection if the potential irregularities are evenly spaced even though the spacing is of the same magnitude as the wave length. Secondly, the intensity of specular reflection should be greater near grazing than near normal incidence. Thirdly, there should be interference maxima in directions other than that of the specular beam. And fourthly, the reflection should be more intense for the longer wave lengths (slower atoms). The wave theory, then, is in qualitative agreement with the experiments in regard to the first two predictions. The fourth prediction has not yet been tested

experimentally. It will be shown that the absence of other diffraction maxima in the intensity distribution represented in Fig. 4 can be attributed to the velocity distribution in the atom beam and the dispersion which exists in such

FIG. 7.



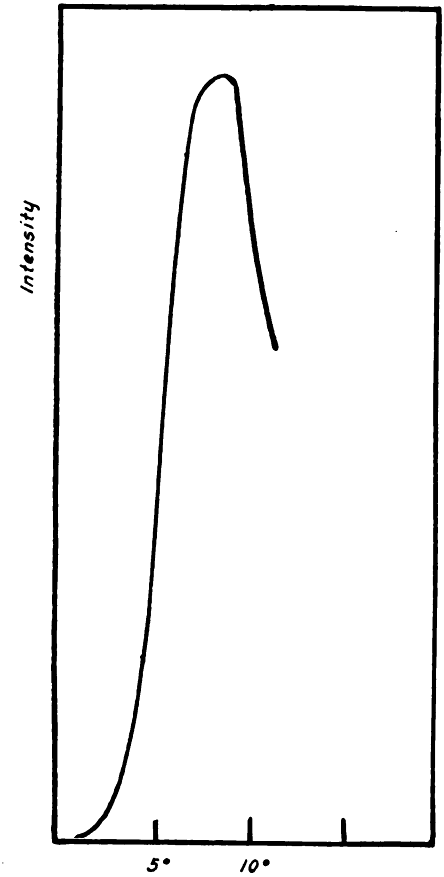
The distribution of intensity in the first order diffraction beam from the surface lattice of rock salt at 60° from grazing incidence, calculated from the wave-length distribution of Fig. 7.

diffraction beams. If we assume the velocity distribution in the discharge tube is Maxwellian, then the corresponding distribution in wave lengths ($\lambda = h/mv$) of the atoms in the beam will be given by

$$dN = (Ae^{-\beta/\lambda^2}d\lambda)/\lambda^5,$$

where β is a constant depending upon the temperature and the mass of the atom. At 200°C., the probable discharge tube temperature, this distribution has a maximum at 0.7 Å. and is represented graphically in Fig. 6. The corre-

FIG. 8.



Calculated intensity of the specular beam assuming Bragg interference.

sponding distribution in angle of the first order diffraction beam after reflection from a surface grating of the spacing of the rock salt crystal (d = 2.56 Å.) at 60° from grazing incidence is represented in Fig. 7. It is seen that this beam is spread over about 50° and its identification, at least in the present stage of the work, is quite unthinkable.

Diffraction effects due to the volume lattice have likewise not been found. If we assume that only those atoms are specularly reflected whose wave-length satisfies the Bragg formula $n\lambda = 2d \sin \theta$ the intensity of the specular beam should vary with the angle, owing to the distribution in wave-lengths, in a manner represented in Fig. 8. Contrary very to this expectation the specular beam undergoes only a slight variation of intensity of small angles. This, however, is not surprising if it is remembered that Davisson and Germer have found that the diffraction effects for electrons reflected near grazing are almost entirely dependent upon the surface grating and not upon the three dimensional lattice. This result is of course to be interpreted to mean that absorption within the crystal becomes very important at small angles.

It is a pleasure to acknowledge the excellent facilities of the Bartol Laboratory and the inspiration and suggestions which have come from my colleagues there, in particular from Dr. W. F. G. Swann. I am also indebted to Professor Barnes of Bryn Mawr College for the use of his densitometer and to Dr. Gordon of the Academy of Natural Sciences, Philadelphia, for several crystals.

The Fluorescent Spectrum of Sodium Vapor in the Vicinity of the D Lines. R. W. WOOD AND E. L. KINSEY. (*Phys. Rev.*, May, 1928.) The investigators sought to find whether fluorescing sodium vapor could be made to emit the D lines under the excitation of monochromatic radiation of any wave-length other than that of these lines themselves. The light of a carbon arc passed to a monochromator from which a beam, embracing a range of wave-lengths equal to 50 Ångstrom units, was directed upon the sodium vapor. Repeated failures were finally followed by success when hydrogen, air or nitrogen were introduced into the fluorescing vapor. "As before the D lines, excited by light in which their wave-lengths were absent, attained their maximum intensity when the pressure was about 3 mm. disappearing at higher or lower pressures, i.e. at 2 and 4 mm. By turning the prisms in the monochromator, the wave-length of the exciting radiations could be altered. It was found that as the exciting beam moved into the blue region from the shorter wave-lengths the D lines appeared feebly, growing stronger until the wave-length of the exciting light lay between 5,100 Å. and 5,250 Å. in the green where they reached their maximum intensity. As the wave-length was increased further the D lines diminished in intensity and finally disappeared until the yellow region was reached where they were again excited by radiation of their own wave-length." Atomic sodium does not show any absorption in the region between the D lines and 3,302 Å. The radiation in this part of the spectrum must therefore be absorbed by sodium in molecular form. "The excited molecule may then cause the D line emission by collisions of the second kind with atoms, or by dissociating, either spontaneously or as a result of collisions with a foreign gas, into a normal and an excited atom."

G. F. S.

MAGNETIC PROPERTIES OF PERMINVAR.

BY

G. W. ELMEN, M.A.

IN 1921 the writer was investigating the magnetic properties of a series of permalloys [1] to which a few per cent. of a third metal was added to the nickel and iron. One of these alloys contained cobalt. Magnetic measurements indicated that up to moderate field strengths the permeability of this nickel, cobalt, iron alloy was remarkably constant. The constancy was materially better than for soft iron, notwithstanding the fact that the initial permeability was several times higher. This was unusual, as small permeability variation ordinarily is found only in materials with low permeability. Measurements of other magnetic properties were equally surprising. When the hysteresis loop was traced for a cycle which carried the flux density up to a few thousand gauss, it was found to have an extraordinary form in that it was sharply constricted in the middle. These and other differences which were observed indicated that this alloy was a new type of magnetic material in which the magnetic properties were fundamentally different from those of previously known materials.

This discovery aroused a great deal of interest for it was recognized that magnetic materials possessing these properties were of great scientific and technical importance. In order to develop the possibilities which this alloy suggested, an exploration of the whole field of the iron-nickel-cobalt series was undertaken. For it was, of course, apparent that the alloy which had aroused our interest must be one of a group of compositions which possessed similar properties in a greater or less degree. In this survey, alloys varying in 10 per cent. steps in composition and including the whole range of the ternary series of these metals were made up and their magnetic properties measured.

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[1] Arnold & Elmen, JOUR. OF FRANK. INST., May, 1923, p. 621.

These measurements showed the range of compositions which shared in such unusual magnetic properties, and indicated that heat treatment was an important factor in the development of these properties. A large number of alloys have been made up in this range, for which the variations in composition were evenly distributed but much smaller than for the initial survey. From these alloys a few were selected which appeared to be specially suited for magnetic uses in electrical communication circuits. Our experience with these alloys has been that when good grades of commercial materials are used, the castings are readily reduced mechanically to the desired dimensions, and the magnetic properties from different castings of the same composition are quite uniform.

We felt that these alloys were so unique as regards magnetic quality that they should be grouped in a class under a common name which should readily distinguish them from other materials. We have chosen "perminvar" as the name for alloys in the iron-cobalt-nickel series, which are characterized, when properly heat treated, by constancy of permeability for a considerable range of the lower part of the magnetization curve, by small hysteresis loss throughout the same range of flux densities, and by a hysteresis loop constricted at the origin for medium flux densities.

This paper describes the magnetic properties of the perminvar group of alloys. Results are given for several alloys selected to show the variation in magnetic properties when the proportions of the constituent metals are varied over a wide range. Detailed measurements under a variety of magnetic conditions and heat treatments are recorded for the composition 45 per cent. nickel, 25 per cent. cobalt and 30 per cent. iron. This composition is a typical one and was chosen early in our experimental work as specially suitable for commercial uses, for it had, in addition to the unusual properties in which we were most interested, a fairly high initial permeability.

PREPARATION OF ALLOYS.

The alloys were cast from the best available commercial materials. Armco iron, electrolytic nickel and commercial

cobalt were melted together in the desired proportions in a silica crucible in a high frequency induction furnace. Before pouring, one-half of one per cent. of metallic manganese was added to the molten metal. Part of this manganese deoxidized the metal and went into the slag, and the remainder, usually about one-half of the added amount, remained in the alloy. The alloys also contained small amounts of carbon (less than .03 per cent.), silicon (less than .1 per cent.) and traces of sulphur and phosphorus. The alloys were cast into bars 18 in. long and 3/4 in. in diameter. The bars were rolled or swedged into 1/4 in. rods and drawn from that size to .062 in. diameter wire. This wire was flattened and trimmed into tape 1/8 in. × .006 in. The material was annealed several times in the reduction process, for the cold working hardened the alloys rapidly and made them difficult to work.

To prepare the tape for heat treatment and subsequent magnetic measurements, about 30 ft. of it was wound spirally into a ring of 3 in. inside diameter, the ends being spot welded to the adjacent turns. Care was taken to wind the rings loosely to prevent the turns of tape from sticking during annealing.

A number of such rings were packed in a nichrome pot. Some iron dust was usually placed in the pot to take up the oxygen and thus prevent the oxidation of the rings. Further protection was secured by luting the joint between the pot and its cover. The pot was placed in an electrical resistance furnace, the temperature of the furnace raised to 1000° C. and held at that temperature for one hour. The current was then turned off and the pot cooled with the furnace. Ten hours were required for the furnace to cool to the temperature of the room. Between 700° C. and 400° C. the rate of cooling was approximately 1.5° per minute.

Three rings of each composition were always annealed together. One of these rings received no further heat treatment. The second ring was placed for 15 minutes in a furnace held at 600° C., then removed and cooled rapidly on a copper plate. In some cases, the third ring was heated 24 hours at 425° C.

In the discussions and in the figures and tables, the rings

which received the first heat treatment only are referred to as "annealed," those reheated to 600° C. and rapidly cooled as "air quenched," and those held for a long time at 425° C. as "baked."

MAGNETIC MEASUREMENTS.

Permeabilities at low magnetizing forces were measured on unwound rings with an inductance bridge, and an a.c. permeameter.[2] From these measurements initial permeabilities were computed. For elevated temperature, measurements were made with a similar permeameter provided with a furnace compartment.[3] The bridge was also used for measuring permeabilities to small a.c. magnetizing forces when d.c. forces are superposed on the magnetic circuit. For these measurements the rings were wound with insulated copper wire after being placed in thin annular wooden boxes to protect them from strain. Hysteresis losses were computed for a few alloys from effective resistance measurements at low flux densities, made on wound rings.

Magnetization and permeability curves and hysteresis loops were plotted from ballistic galvanometer measurements. Galvanometer measurements also were made on a few alloy rods 11 in. long and 1/8 in. diameter, at a magnetizing force of 1,500 gauss. For these measurements the rods were placed in a long solenoid and the induction measured by means of an exploring coil at the center of the rod.

PROPERTIES OF THE 45 PER CENT. Ni, 25 PER CENT. Co, 30 PER CENT. Fe, COMPOSITION.

Measurements for the composition 45 per cent. nickel, 25 per cent. cobalt and 30 per cent. iron in the annealed condition are plotted in Figs. 1–7 and tabulated in Table I. The curves in Fig. 1 illustrate the permeability characteristics for this composition (No. 858–1) and for a sample of annealed Armco iron. For magnetizing forces below 1.7 gauss, the permeability is substantially constant, the variation being less than 1 per cent. This constancy is remarkable for a magnetic material having an initial permeability nearly double that of iron. Within the same range of field strengths the

[2] G. A. Kelsall, *J. O. S. A.* and *R. S. I.*, **8**, pp. 329–338, 1924.

[3] G. A. Kelsall, *J. O. S. A.* and *R. S. I.*, **8**, pp. 669–674, 1924.

permeability of the iron sample rises from an initial value of 250 through a maximum of 7,000 at a magnetizing force of 1.3 gauss and decreases to 6,300.

TABLE I.

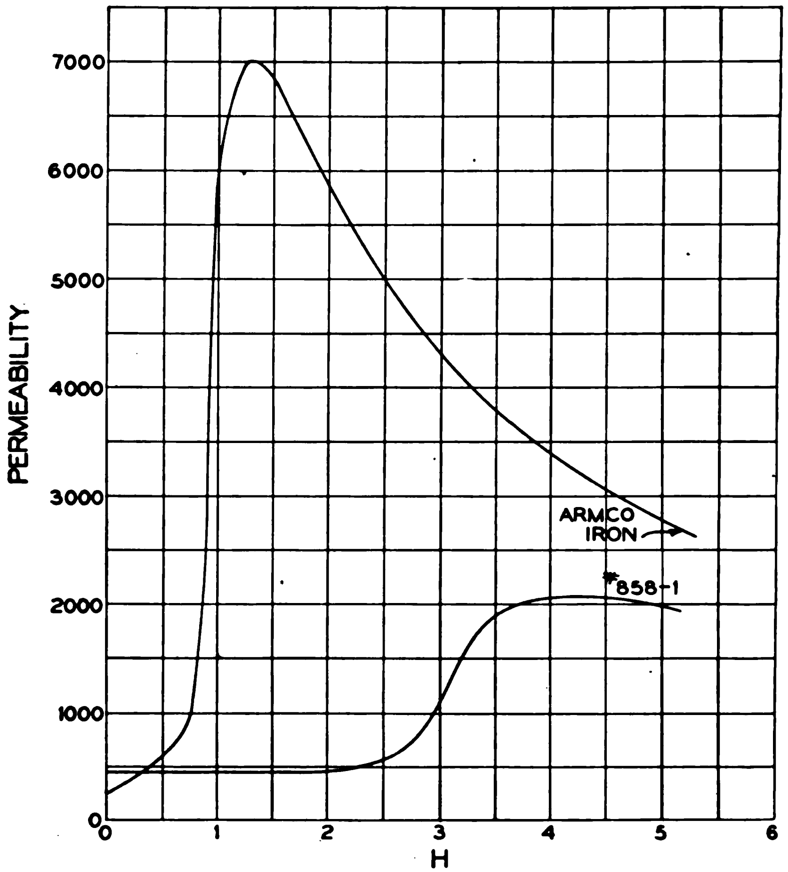
Hysteresis Loss with Different Heat Treatments for [45% Ni—25% Co—30% Fe] *Composition Perminvar.*

Heat Treatment.	*B.*	Ergs per Cm.[3] per Cycle.
Air Quenched	568	18.7
	722	32
	993	57
	1,503	119
	5,010	850
	14,810	2,500
Baked at 425° C. for 24 Hours	600	0
	795	0
	1,003	15.27
	1,604	163
	4,950	1,736
	13,810	4,430
Annealed	570	0
	820	9.54
	974	15.65
	1,508	93.20
	5,050	1,185
	8,480	2,500
	14,900	3,375

Another property of the perminvar alloy closely related to the constancy of permeability is the extremely small hysteresis loss in the range of magnetizing forces and flux densities in which the permeability is constant. This is illustrated in Fig. 2 where line *a* represents the plot of the upper half of the hysteresis loop for a maximum flux density of approximately 600 gauss. Curves *b* and *c* are similar plots for Armco iron and silicon steel ($3\frac{1}{2}$ per cent. silicon) respectively. While the hysteresis loops for Armco iron and silicon steel have considerable areas amounting to 33 and 14 ergs per cubic centimeter per cycle respectively, there is no measurable area for the perminvar alloy. Although the ballistic method of measurements which was used in obtaining these curves, does not indicate very small losses readily it is evident that the losses in the perminvar alloy are of a different order of magnitude from those of the other two materials.

In order to obtain additional information in regard to the hysteresis loss of this alloy at low flux densities, the sample was measured by the inductance bridge method. It was found that the hysteresis loss at a flux density of 100 gauss was .024 $\times$ 10^{-3} ergs per cubic centimeter per cycle. The

Fig. 1.

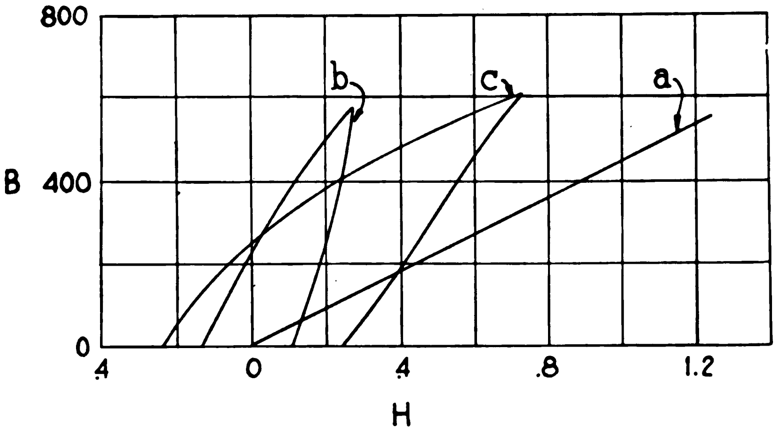


Permeability curves for Armco iron and Perminvar (45% Ni—25% Co—30% Fe).

best material in this regard previously known was permalloy, for which a sample containing approximately $78\frac{1}{2}$ per cent. nickel, measured under similar conditions, had a hysteresis loss of 33 $\times$ 10^{-3} ergs per cubic centimeter per cycle.

The growth of the hysteresis loss and the appearance of measurable areas, and the peculiar shapes of the loops for this composition as the flux densities increase are illustrated in Fig. 3. The curve for a maximum flux density of 580

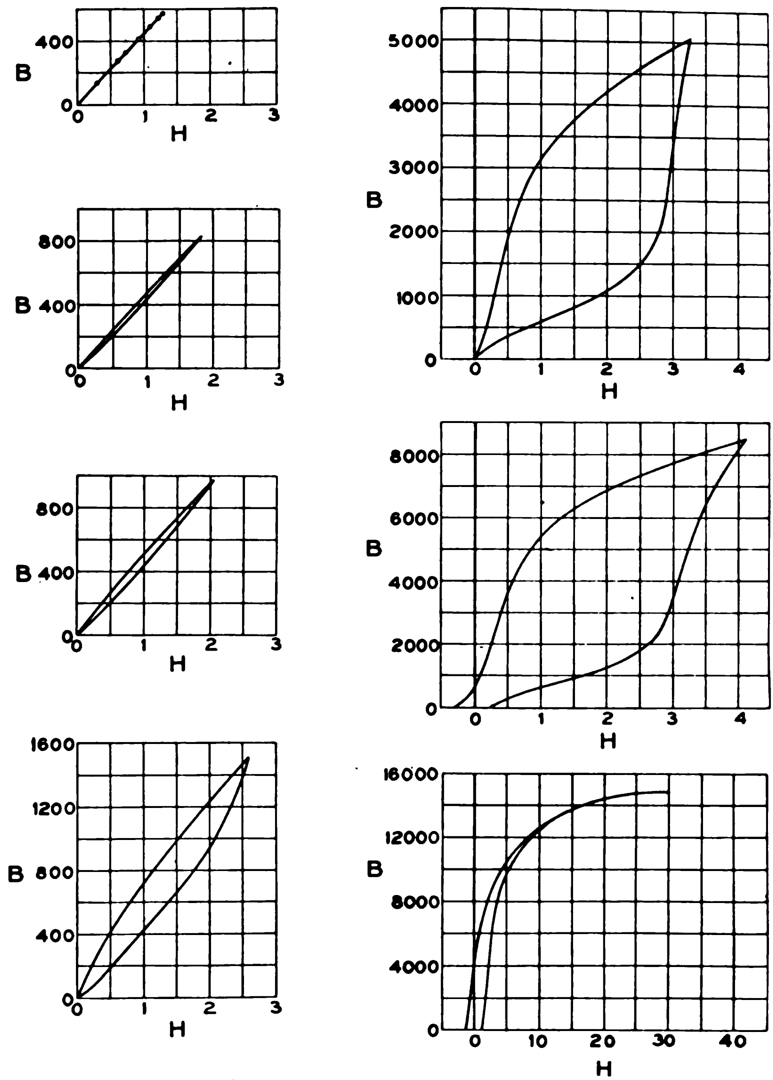
FIG. 2.



Hysteresis characteristics: *a*—Perminvar (45% Ni—25% Co—30% Fe); *b*—silicon steel; *c*—Armco iron.

gauss in Fig. 3, is from the same data as Curve *a* in Fig. 2. The circles in this plot indicate points on the ascending branch, and the dots, points on the descending branch. The hysteresis loop broadens out so that it has a measurable area when the maximum flux density is increased to 800 gauss. The existence of a close relation between the hysteresis losses and the constancy of permeability is quite apparent from the permeability curve in Fig. 1 and the curves in Fig. 3. While the permeability remains constant there is practically no hysteresis loss but as it begins to change this loss appears and increases quite rapidly with increase in permeability. The increase in the energy loss and the changes in the shapes of the loops as the flux density increases also are illustrated by these curves. The most striking hysteresis characteristic of these loops is the absence of coercivity. For loops having maximum flux densities of 5,000 or less the ascending and descending branches pass through the origin. For greater flux densities the coercivity begins to be measurable, but there is still a considerable constriction of the loop for a

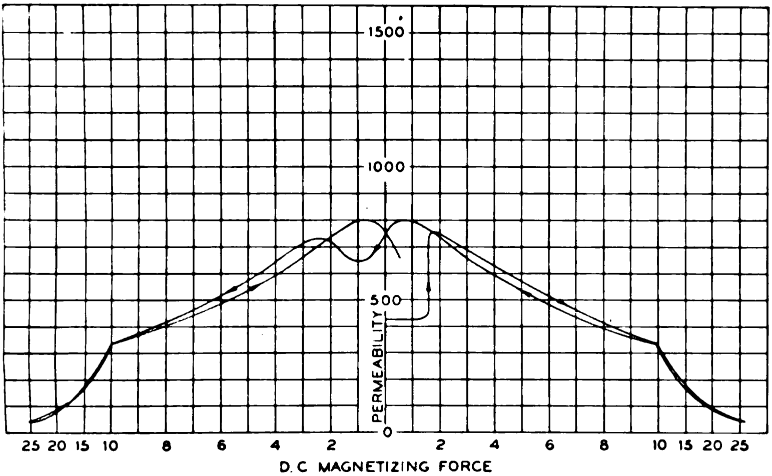
Fig. 3.



Upper halves of hysteresis loops of Perminvar (45% Ni—25% Co—30% Fe) annealed.

maximum flux density of 8,000 gauss. It is only in the loop for 15,000 gauss, that the constriction at the origin has disappeared and the loop resembles those for ordinary magnetic materials. In Table I the hysteresis losses for the complete loops are tabulated.

FIG. 4.



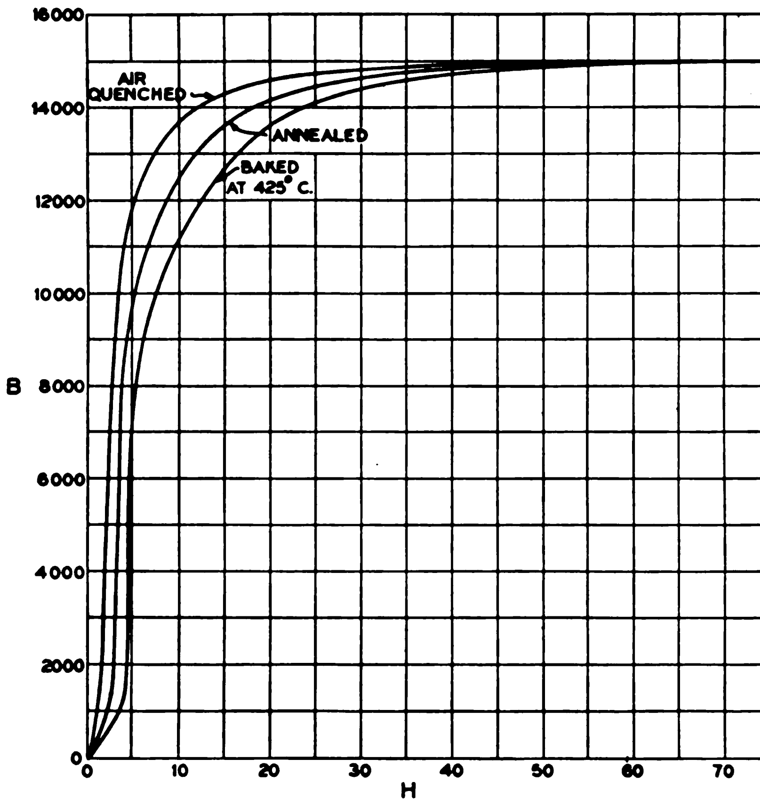
The effect of superposed d.c. fields on the a.c. permeability of Perminvars (45% Ni—25% Co—30% Fe).

Fig. 4 illustrates graphically how the permeability measured with a constant alternating current magnetizing force of about .0021 gauss and 200 cycles per second is affected when a steady magnetizing force is superposed on the magnetic circuit, the steady force being produced by a direct current. The arrows in the figure indicate the direction in the progress of the permeability as the direct current magnetizing force is varied. The permeability is substantially constant as the direct current magnetizing force increases up to approximately 1.7 gauss and it then suddenly rises as the force is increased beyond that value. This is the same field strength at which the permeability begins to increase as shown in Fig. 1.

Another characteristic of this material not found in ordinary magnetic substances also is shown in Fig. 4. After an applied d.c. magnetizing force of 25 gauss is removed,

the permeability has risen from 460 to 750. With ordinary materials, after such magnetization, the permeability is reduced, in some cases from 40 to 60 per cent. With the increase in permeability its constancy disappears both for the

FIG. 5.



Magnetisation curves for Perminvar (45% Ni—25% Co—30% Fe).

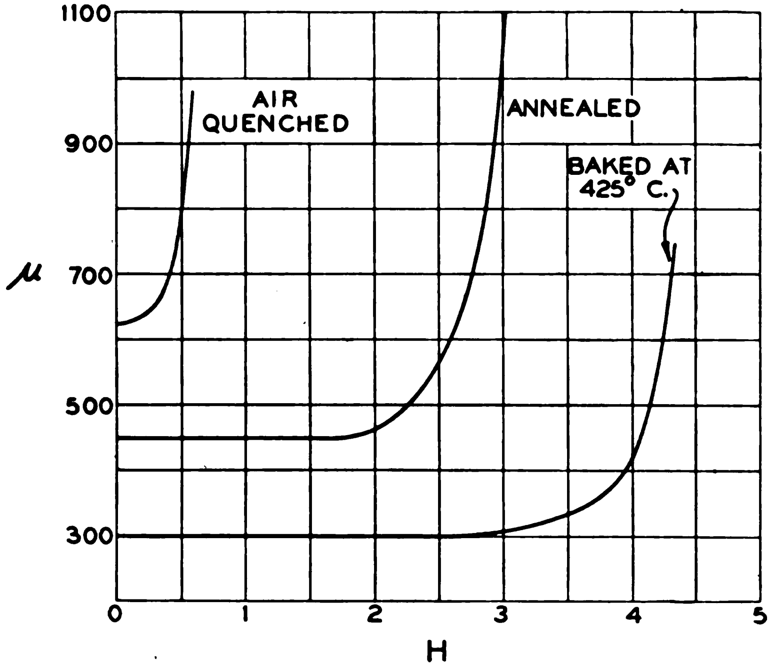
superposed condition as shown in Fig. 4, and for ordinary magnetizations at low field strengths. The hysteresis losses are also increased for corresponding flux densities. These changes in the magnetic properties are largely removed by demagnetization. The ordinary methods of demagnetization by reversals of a slowly decreasing magnetizing force has been less successful than it is with iron in returning the material to its initial state. Addition of an a.c. force

superposed on the d.c. helps materially in restoring the original magnetic properties.

EFFECTS OF HEAT TREATMENT.

The manner in which the magnetic properties of this composition are affected by the rate of cooling is illustrated in Figs. 5–7. The measurements plotted in these figures are

FIG. 6.

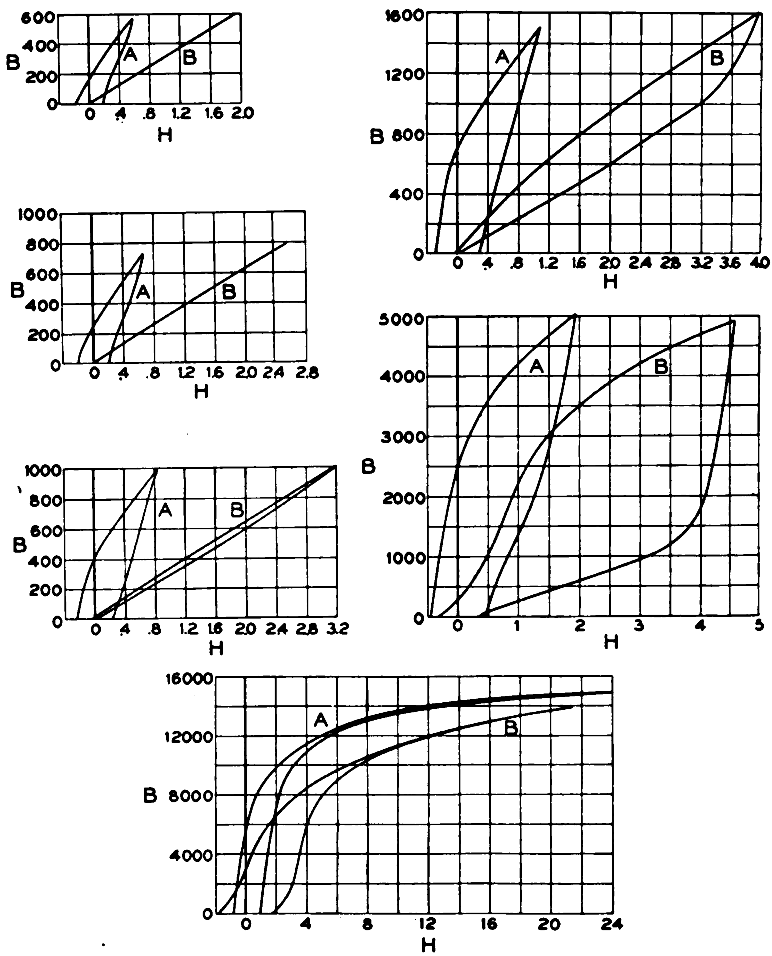


Permeability curves for Perminvar (45% Ni—25% Co—30% Fe).

from three rings, air quenched, annealed and baked, respectively. For weak fields there are large differences in the magnetic properties for these rings. The initial permeability for the quenched ring is more than twice that of the baked one. With increased field strength this difference decreases and disappears for fields over 50 gauss. The permeability variations as the strength of the field increases also show the remarkable change which heating for a long time in the critical temperature range produced in these alloys. For the

quenched ring the permeability increased from 620 to 800 for an increase of field strength from 0 to .5 gauss. For the baked ring the permeability remains constant for fields up to 2.5 gauss.

FIG. 7.



Upper halves of hysteresis loops for Perminvar (45% Ni—25% Co—30% Fe)
A—air quenched, *B*—baked at 425° C.

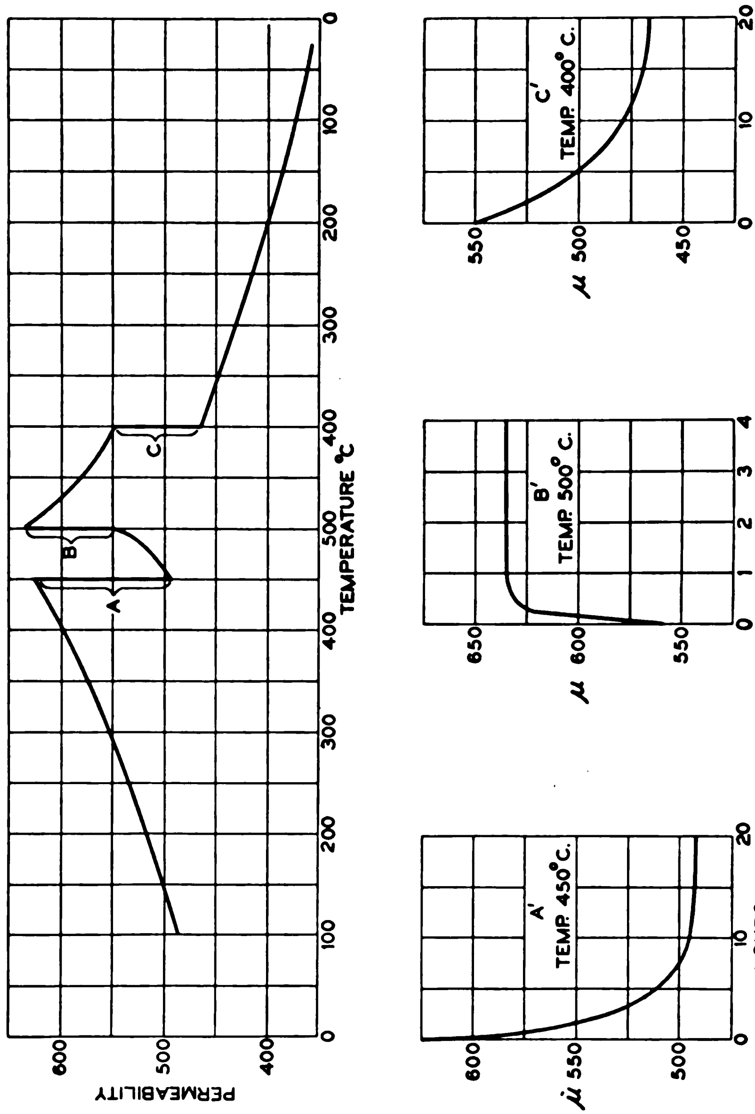
The hysteresis loss and the shapes of the loops also are affected greatly by the heat treatment. This is illustrated

in Fig. 7, where loops for a number of flux densities are plotted for two sample rings, one baked at 425° C. and the other air quenched, and in Fig. 3 where loops for the same maximum flux densities are plotted for an annealed ring. The energy losses integrated for complete loops are tabulated in Table I.

These curves show that the rate of cooling determines the magnitudes of the hysteresis losses and the shapes of the hysteresis loops. For the air quenched rings the shapes of the loops for the different flux densities resemble those for ordinary magnetic materials although a few of them show traces of the perminvar characteristics. If a more rapid cooling rate had been used these characteristics no doubt would have disappeared completely. The hysteresis loops all have considerable areas. The one for 568 gauss, the lowest flux density measured, represents an energy loss of 18.7 ergs per centimeter cube. For the same flux density, the hysteresis loops for the annealed and the baked rings have no measurable areas, the ascending and descending branches of the loops falling on the straight lines shown in the figure. This absence of measurable area extends up to a flux density of nearly 1,000 gauss for the baked ring. The increase of energy loss as the flux density increases above this value, however, is considerably more rapid than for the quenched ring. At 1,500 gauss, the hysteresis loss is a little greater than for the quenched ring and when the flux density is increased to 5,000 gauss, the loss is more than double.

It was shown above that the degree to which perminvar characteristics are developed depends on the rate of cooling through the critical temperature range, and that baking at 425° C. gave the most characteristic results. The manner in which the permeability of the 45 per cent. nickel, 25 per cent. cobalt and 30 per cent. iron composition changes in this temperature range is illustrated in Fig. 8. The temperature of an annealed ring was increased from that of the room to 450° C. where it was held constant for twenty hours. It was then raised to 500° C. and held for four hours, then lowered to 400° C. where it was held for twenty hours, and finally cooled to room temperature. Permeability measurements were made at these temperatures with an a.c. magnetizing force of .02 gauss.

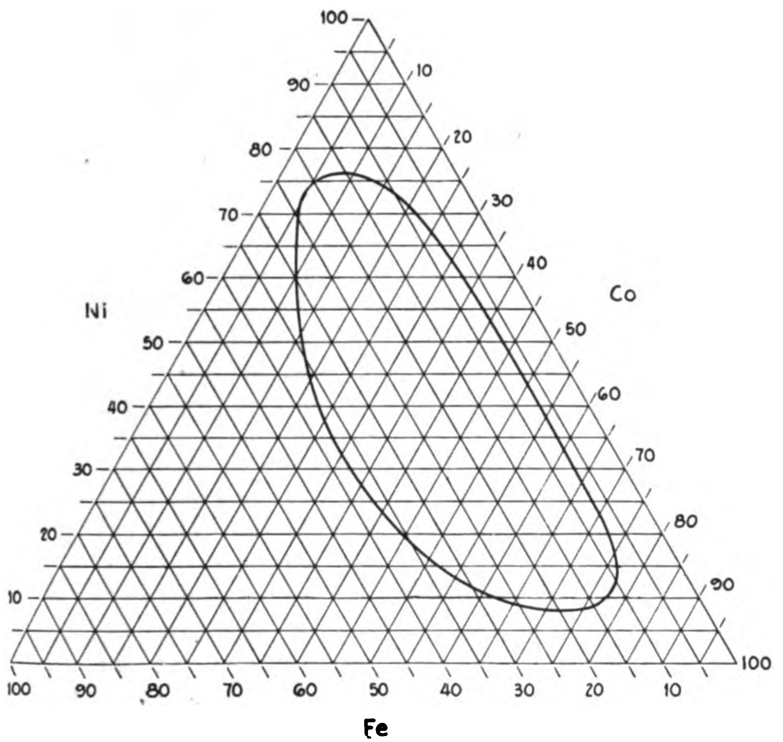
FIG. 8.



Permeability—Temperature curve for Perminvar (45% Ni—25% Co—30% Fe).

Inspection of these curves shows that in the range 400°–500° C., the permeability lags behind the temperature, and that the time required for the permeability to reach a constant value increases very rapidly below 450° C. The changes in final permeabilities with temperature decrease also rapidly

FIG. 9.



Composition diagram Ni—Fe—Co Series. Area enclosed by the curve shows compositions with marked Perminvar characteristics.

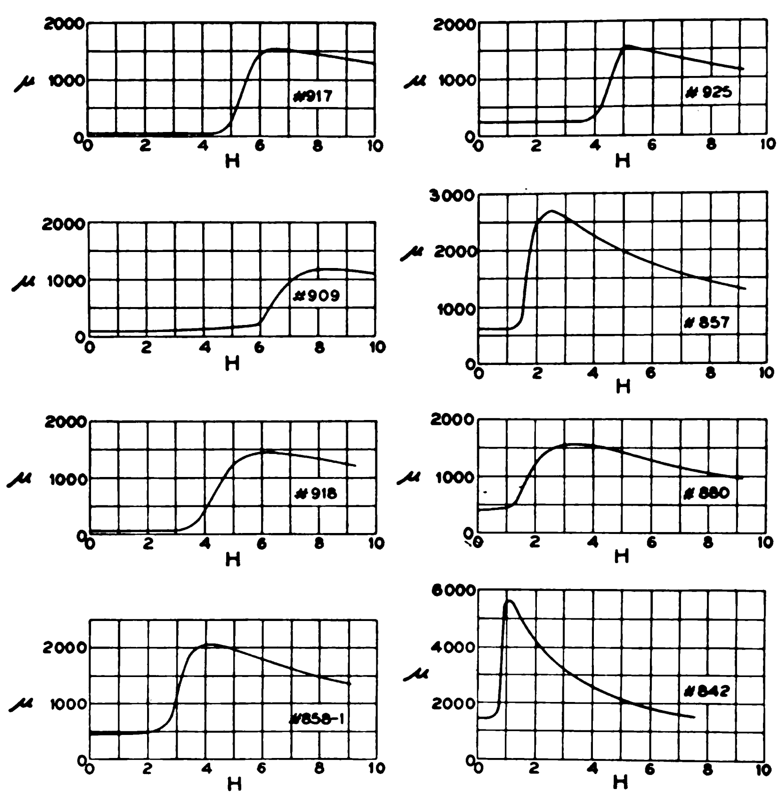
below 450° C. In fact, when the difference in permeability caused by the temperature coefficient is corrected for, the permeability of the alloy after heating at 400° C. is not very different from what it is after heating at 450° C. Other experiments show that the critical temperature range extends below 400° C., but, as would be expected, the decrease in permeability is very small. The range also extends above 500° C. for this alloy and some experiments indicate that

the upper limit is the magnetic transformation temperature which for this alloy is 725° C.

EFFECTS OF VARIATION OF COMPOSITIONS.

The composition range within which the magnetic properties characteristic of perminvar are developed pronouncedly by annealing, is represented by the area enclosed by the

Fig. 10.



Permeability curves for several compositions of Perminvar. Chemical analysis given in Table II.

curve in the triangular composition diagram Fig. 9. Magnetic properties for a few of the compositions in this area are plotted in Figs. 10 and 11. Table 2 gives their chemical analyses, initial permeability (μ_o), the maximum permeability ($\mu_{max.}$), the magnetizing forces (H) and the flux densities (B)

in gauss to which the alloys may be brought with a permeability variation not over 1 per cent., also the $(B - H)$ values for a magnetizing force of 1,500 gauss for some of the alloys, and the resistivity in microhms-cm. The hysteresis losses for a number of flux densities are given in Table 3.

TABLE II.

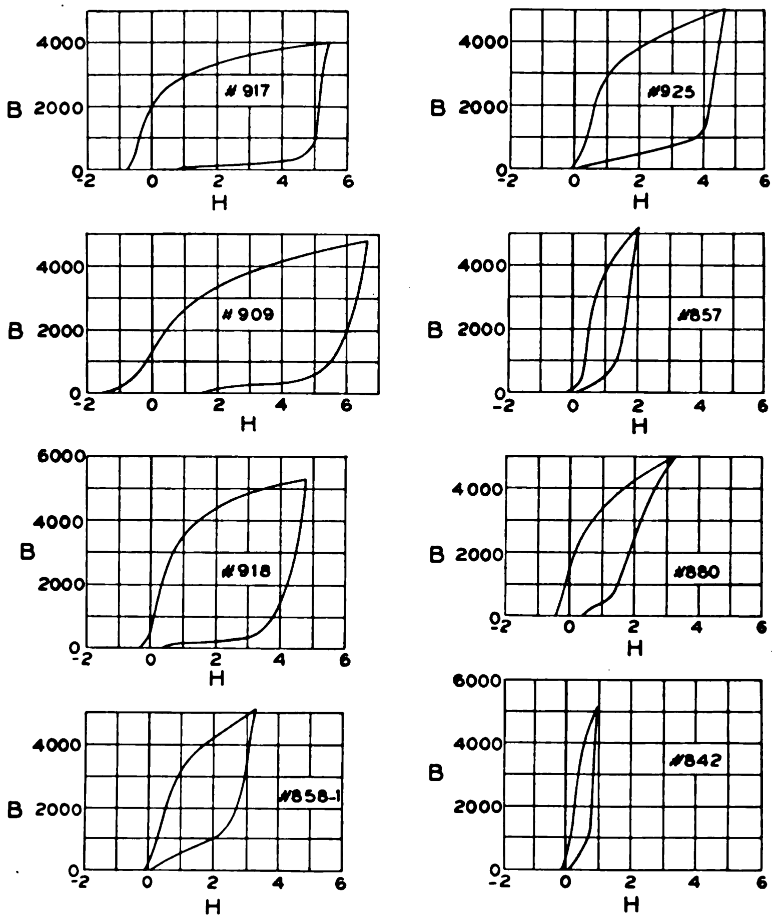
Chemical Composition and Magnetic Properties of Perminvars.

Casting Number.	Chem. Analysis.				Magnetic Properties.					Resistivity.
	Ni.	Co.	Fe.	Mn.	μ_0.	μ_m.	H for 1% Ch. in μ.	B for 1% Ch. in μ.	$B-H$ for $H = 1,500$	Microhm-Cm.
917	11.35	68.10	20.36	.35	57	1,545	4.2	242	18,400	15.38
909	20.85	49.18	29.74	.31	98	1,180	4.0	396	18,200	16.59
918	20.73	68.35	10.58	.39	51	1,447	2.5	129	17,400	12.35
858–1	45.12	23.83	30.69	.46	449	2,075	1.75	793	15,600	18.63
925	50.47	29.28	20.15	.33	231	1,555	3.2	746	14,600	14.55
857	59.66	14.76	24.97	.60	631	2,680	1.15	733		17.5
880	70.29	15.23	14.57	Tr.	390	1,570	.55	216		14.13
842	73.29	5.97	20.7	.20	1,430	5,600	.55	795		15.56

The area enclosed in Fig. 9 shows that approximately one-third of the alloys in the Ni-Fe-Co series show some of the characteristic perminvar properties in the annealed condition. The proportions of nickel and cobalt may be varied through a wide range. A great deal less variation in the iron content is permissible, being less than one-half of the amounts of the other two constituents. The manner in which each of the metals affects the magnetic properties is not very clearly indicated by the numerical values in the table. Iron and cobalt appear to increase the constancy of the permeability but decrease the initial permeability values. Nickel increases the initial permeability but large percentages decrease the constancy. On the whole, in the alloys with high nickel content, the combination of high permeability and fair constancy makes for a larger range of flux densities

in which the permeability is constant and consequently also increases the range of flux densities with low hysteresis loss.

FIG. 11.



Upper halves of hysteresis loops for several Perminvar compositions. Chemical analysis is given in Table II.

Experiments on several alloys of this series indicated that by baking the alloys at 425° C. the area enclosed by the curve in Fig. 8 would be increased considerably, and possibly would include some of the binaries of these metals.

TABLE III.

Hysteresis Loss.

Casting Number.	*B.*	Ergs per Cm.^{3} per Cycle.	*B.*	Ergs per Cm.^{3} per Cycle.	*B.*	Ergs per Cm.^{3} per Cycle.	*B.*	Ergs per Cm.^{3} per Cycle.	*B.*	Ergs per Cm.^{3} per Cycle.
917	280	8	625	150	1,700	1,040	3,950	2,740	15,500	14,160
909	—	—	620	36	1,030	299	4,800	3,330	15,200	12,460
918	—	—	750	247	—	—	5,270	2,605	—	—
858–1	566	0	827	9.5	1,508	93	5,050 8,480	1,185 2,500	14,900	3,375
925	560	0	—	—	2,000	468	5,000	2,020	13,200	4,965
857	145	0	840	8.4	1,520	88	5,200 8,250	632 1,240	13,250	1,508
880	320	0	—	—	1,470	116	5,000	1,012	10,300	2,435
842	500	0	—	—	1,530	23	5,100	348	11,500	783

DISCUSSION.

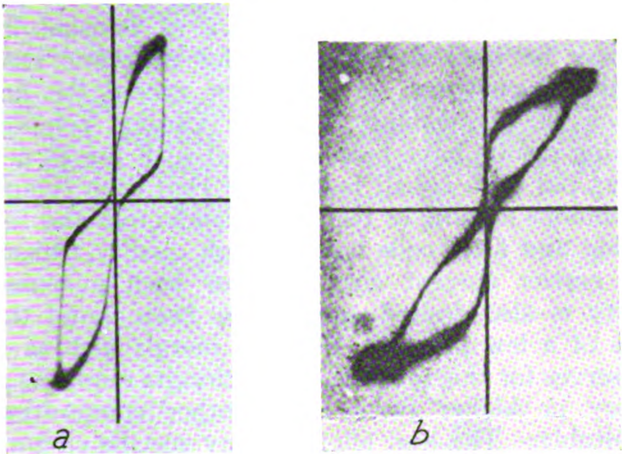
While this paper is concerned primarily with the study of the magnetic properties of these alloys and the dependence of these properties on composition and on heat treatment, some of the results are of considerable theoretical interest, as they suggest the manner in which the unusual magnetic properties are acquired by the alloys. It was shown in the heat treating experiments that the unusual magnetic properties resulted from suitable heat treatment of certain compositions. Slow cooling through a rather narrow temperature range, or continuous heating for a long time at the lower end of this range resulted in alloys which had marked perminvar characteristics. Rapid cooling through this temperature range usually did not develop these characteristics. From the measurements at elevated temperatures, Fig. 8, it was shown that in the temperature range from 400° C. to 500° C., the change in the alloys is quite rapid at the higher temperature, but that the rate of stabilization slows up as the temperature decreases. When the alloy is heated and cooled through a temperature cycle in this manner, the permeability changes progressively and at each temperature in the cycle the alloy reaches a stable condition if the rate of cooling or heating is slow enough. There is a striking similarity in the manner in which these changes in permeability are developed, and in the progress of the constitutional changes in an alloy which at high temperatures is a homogeneous solid solution, but as the temperature falls becomes saturated and segregates into a mixture of two solid solutions of different concentration.

That such a segregation takes place in the slowly cooled alloys is also supported by a study of the differences in the shapes of the hysteresis loops of the quenched and the slowly cooled alloys. Ordinarily, the widest part of a hysteresis loop of a homogeneous material is the intercept on the H axis. All the loops of the air-quenched alloys have these characteristics. Gumlich [4] has shown that if a magnetic circuit is made up two materials of different magnetic properties, the loops may assume a variety of shapes, ranging from that

[4] E. Gumlich, Arch. f. Elektretechnik, Vol. 9, p. 153, 1920.

of the homogeneous material to one in which two branches converge at the origin into a single line. This constriction of the hysteresis loop is also illustrated for a parallel bi-metallic magnetic circuit in Fig. 12 where loops *a* and *b* are

FIG. 12.



Hysteresis loops: *a*, Perminvar; *b*, Bi-metallic rod. Loops traced with a cathode ray oscillograph.

traced for a perminvar core and a bi-metallic rod, respectively. The rod was 15 in. long and consisted of a core of .04 in. diameter unannealed piano wire and a .006 in. wall permalloy tube, heat treated to give high permeability, and fitting closely to the wire. Though the magnetic circuit condition for the perminvar core is not the same as for the bi-metallic rod, the similarity of the two loops is marked and supports the theory that the constricted loop of the perminvar core is caused by segregation in the alloy.

The electrical resistance also is affected by the slow cooling. An air-quenched alloy of the 45 per cent. nickel, 25 per cent. cobalt and 30 per cent. iron composition was 10 per cent. lower in resistivity after it had been baked at 425° C. This change is also in line with the idea that segregation takes place when the perminvar alloys are cooled slowly.

While these considerations point to a satisfactory explanation for the constriction of the hysteresis loops they do not

explain the extremely low hysteresis losses of the alloys at low flux densities. This characteristic of perminvar suggests that one of the constituents which is segregated by the heat treatment is itself a material of much lower hysteresis loss than any previously known material and that the other constituent suffers relatively little change of magnetization at low magnetizing forces.

To the engineer these alloys are of unusual interest. They may be used to advantage for magnetic structures where the magnetizing forces do not exceed the limits of constancy of permeability for the various compositions. Interesting results have been obtained with the 45 per cent. nickel, 25 per cent. cobalt and 30 per cent. iron composition for continuous loading of telephone conductors and for cores of loading and filter coils used in high quality transmission and in carrier current circuits. For such purposes high resistivity is also desired, and it has been found that the addition of a few per cent. of other metals such as molybdenum serves for this purpose. For circuits requiring greater constancy or higher permeability other compositions are more suitable. The best alloy for any specific circumstance may be selected from a study of the magnetic properties of the various compositions.

Bell Telephone Laboratories,
New York, N. Y.,
July 9, 1928.

THE MAGNETIC FIELD INTENSITY AT ANY POINT IN THE PLANE OF A CIRCULAR LOOP.

BY

ALBERT P. STROM, M.S.E.E.

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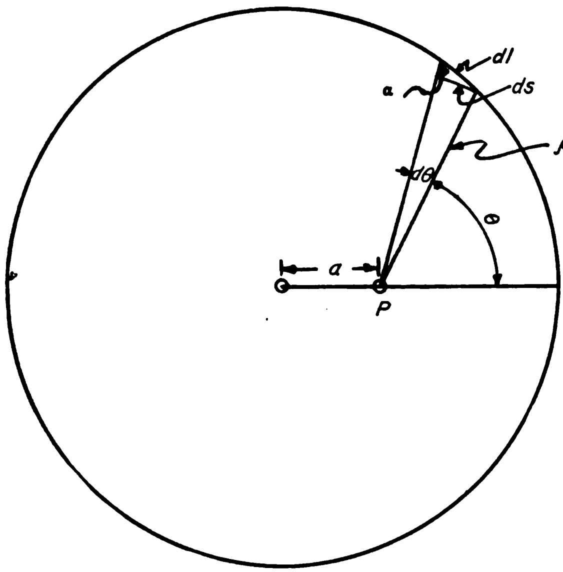
IN this paper a method is developed for calculating the magnetic field intensity at any point in a circular loop in which an electric current flows. This method is based upon the familiar relation given in Ampere's law,

$$H = \frac{I \cdot dl \cdot \sin \alpha}{\rho^2}.$$

FIG. 1.



The problem of calculating the field intensity at the center of such a loop is used in most treatises on magnetism, and has become one of the classical examples of the application

of Ampere's Law. For this special case the problem is much simplified, since I, ρ, and sin α are all constants (ρ = radius; sin α = 1), whence,

$$H = \frac{I}{r^2}\Sigma dl = \frac{2\pi r I}{r^2} = \frac{2\pi I}{r}.$$

When, however, the point at which the field intensity is desired is not at the center, neither ρ nor sin α remain constant, and the problem becomes much more involved. A solution for this general case is given below. Referring to

FIG. 2.

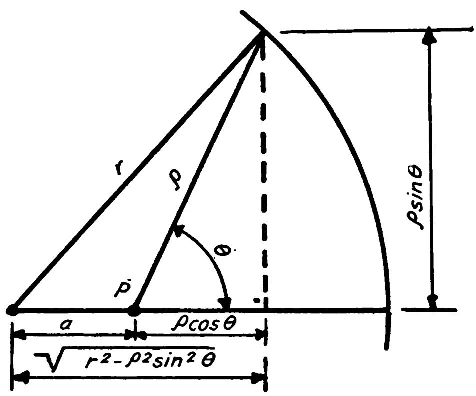


Fig. 1, consider the point P, distant a centimeters from the center. Any increment, dl, of the circle located at an angle, θ, from the radius upon which P lies, produces a field intensity at P, of

$$dH = \frac{I dl \sin\alpha}{\rho^2} = \frac{I ds}{\rho^2},$$

where ds is the projection of dl, on a plane perpendicular to ρ, ρ being the distance from P to dl. I is the current in the wire in abamperes. But, $ds = \rho d\theta$, whence,

$$dH = \frac{I\rho d\theta}{\rho^2} = \frac{I d\theta}{\rho}. \qquad (1)$$

The field intensity at any point P, distant a centimeters from the center is then

$$H_a = \int_0^{2\pi} \frac{Id\theta}{\rho}. \tag{2}$$

In the above integral, ρ as well as θ, is variable, and hence must be expressed in terms of θ before integration is possible. To evaluate ρ in terms of θ, consider the diagram in Fig. 2.

Referring to this figure it is seen that

$$\sqrt{r^2 - (\rho \sin \theta)^2} - a = \rho \cos \theta;$$
$$\sqrt{r^2 - \rho^2 \sin^2 \theta} = a + \rho \cos \theta.$$

Squaring both sides gives

$$r^2 - \rho^2 \sin^2 \theta = a^2 + 2a\rho \cos \theta + \rho^2 \cos^2 \theta,$$
$$r^2 - a^2 - \rho^2(\sin^2 \theta + \cos^2 \theta) - 2a\rho \cos \theta = 0.$$

But since $(\sin^2 \theta + \cos^2 \theta) = 1$,

$$\rho^2 + (2a \cos \theta)\rho + (a^2 - r^2) = 0.$$

Solving for ρ,

$$\rho = - a \cos \theta \pm \sqrt{a^2 \cos^2 \theta + (r^2 - a^2)}. \tag{3}$$

Since ρ is always positive and real, the quantity under the radical must be positive, and the sign before the radical must also be positive.

Substituting the value for ρ as found in equation (3), into equation (2), gives

$$H_a = I \int_0^{2\pi} \frac{d\theta}{- a \cos \theta + \sqrt{a^2 \cos^2 \theta + (r^2 - a^2)}}. \tag{4}$$

Multiplying numerator and denominator in (4), by the conjugate of the denominator, gives

$$H_a = I \int_0^{2\pi} \frac{- a \cos \theta - \sqrt{a^2 \cos^2 \theta + r^2 - a^2}}{a^2 \cos^2 \theta - a^2 \cos^2 \theta - r^2 + a^2} d\theta,$$

whence

$$H_a = \frac{I}{r^2 - a^2}\int_0^{2\pi} a \cos \theta d\theta$$
$$+ \frac{I}{r^2 - a^2}\int_0^{2\pi} \sqrt{a^2 \cos^2 \theta + (r^2 - a^2)} \cdot d\theta. \quad (5)$$

Upon integration the first part of equation (5),

$\frac{I}{r^2 - a^2}\int_0^{2\pi} a \cos \theta d\theta$, vanishes leaving

$$H_a = \frac{I}{r^2 - a^2}\int_0^{2\pi} \sqrt{a^2 \cos^2 \theta + (r^2 - a^2)} \cdot d\theta. \quad (6)$$

Equation (6) may be transformed by letting

$$a^2 \cos^2 \theta - a^2 = - a^2 \sin^2 \theta,$$

whence

$$H_a = \frac{I}{r^2 - a^2}\int_0^{2\pi} \sqrt{r^2 - a^2 \sin^2 \theta} d\theta,$$
$$= \frac{Ir}{r^2 - a^2}\int_0^{2\pi} \sqrt{1 - \frac{a^2}{r^2} \sin^2 \theta} d\theta. \quad (7)$$

Equation (7) is a common type of elliptic integral (for its evaluation see Pierce's Table of Integrals, form 527), and has the following value:

$$\int_0^{\phi} \sqrt{1 - k^2 \sin^2 \theta} d\theta = \frac{2}{\pi} \phi E + \sin \phi \cdot \cos \phi,$$

where E is an elliptic integral, the value of which for any particular value of k, may be found in a table of elliptic integrals. K, in equation (7) is a/r; ϕ, the upper limit, in equation (7), is 2π. Substituting these values gives for the integral,

$$\int_0^{2\pi} \sqrt{1 - \frac{a^2}{r^2} \sin^2 \theta} d\theta = \left[\frac{2}{\pi} \cdot 2\pi E + \sin 2\pi \cdot \cos 2\pi \right] = 4E.$$

Hence the value of equation (7) is

$$H_a = \frac{Ir}{r^2 - a^2} \cdot 4E. \quad (8)$$

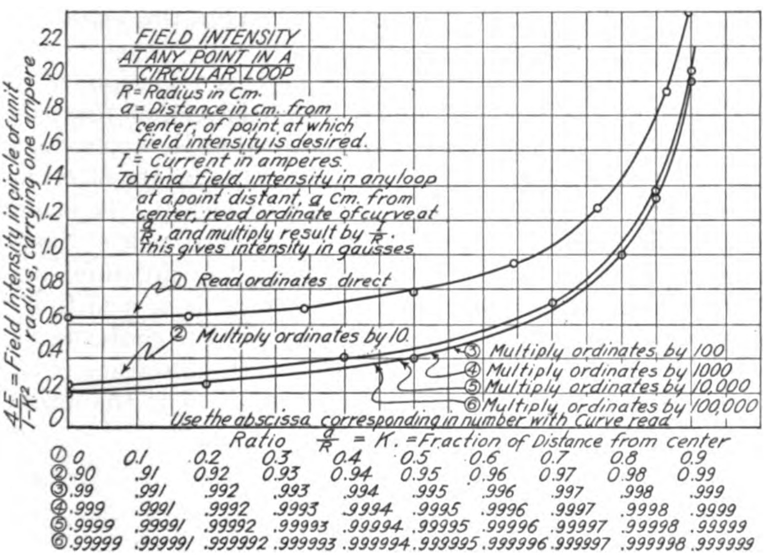
Equation (8) gives the field intensity at any radius a centimeters from the center of a circular loop of wire carrying a current, I abamperes. For any particular value of $k = a/r$, the value of E may be found directly from a table of elliptic integrals.

As a check, let us consider the field intensity at the center of the loop. Here, $k = 0$; $E = \pi/2$; whence

$$H = \frac{Ir2\pi}{r} = \frac{2\pi I}{r}.$$

This agrees with the result obtained by applying Ampere's Law directly as illustrated at the beginning of this paper.

FIG. 1A.



It will be noted that the field intensity, H, as determined in equation (8), becomes infinite when $a = r$. This results because the preliminary assumption, $dH = Ids/\rho^2$, holds only for points outside the conductor itself. Hence equation (8) is valid for all values of a less than $(r - s)$, where s is the radius of the conductor, but does not hold for greater values of a.

Equation (8) may be expressed in terms of k, by dividing numerator and denominator by r^2, whence

$$H_a = \frac{I}{r}\left[\frac{4E}{1 - k^2}\right]. \tag{9}$$

If in equation (9), the term, $4E/(1 - k^2)$, is plotted against values of k, then the resulting curve ordinates, read at the abscissa a/r, when multiplied by I/r, will give the field intensity at any radius a, centimeters from the center of any loop the radius of which equals r centimeters. Such a curve has been drawn in Fig. 1A. This curve has been divided into a number of sections as may be seen in the figure. By this scheme it was possible to use a combination of scales that permit fairly accurate reading of the curve, even for values of k approaching 1, where the value of the ordinate is increasing very rapidly.

It is rather interesting to note the variation of field intensity as the point P, moves from the center toward the circumference of the loop. This variation is shown best on curve No. 1, Fig. 1A, since in this curve the height of ordinate is directly proportional to the field intensity. It is noted that while the field intensity remains quite nearly constant near the center, it rises very rapidly as the circumference of the loop is approached. From this curve it is seen that the field intensity at 0.8 of the distance from the center is about 2.3 that at the center; at k equals 0.9, the intensity is about 4 times that at the center, and at k equals 0.99 the intensity is about 33 times that at the center.

THE USE OF A BROAD FOCUS COOLIDGE TUBE IN ACCURATE RADIOGRAPHIC LOCALIZATION.

BY

OTTO STUHLMAN, Jr., Ph.D.,

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In the localization of foreign bodies in the human anatomy or in parallel cases, in the localization of imperfections in technical structures, there are, generally speaking, three principal methods by which information of a quantitative nature is obtained concerning the position of an imbedded invisible body.

(1) By viewing with a screen or making radiographs of the suspected region in two directions taken at right angles to each other.
(2) By stereoscopic methods.
(3) By triangulation.

Where speed is not the governing factor but where a permanent, accurate record is of paramount importance, or where the structure other than the human anatomy is too thick for fluoroscopic examination, then the triangulation method supplemented by a radiographic plate record must be resorted to.

The scientific requirements of a good triangulation method are that it should possess simplicity, reproducibility and accuracy. In its simplest form, the target of the Coolidge tube is set at a predetermined distance H above the film. Two exposures are made of the body on the same film, the first with the target vertically above the body and the second, after the target has been shifted a known distance, "X," in a horizontal direction. The film now shows two shadows, the second displaced a small distance, "d," parallel to the first. In Fig. 1 is shown the geometry of these positions drawn to scale. Here h is the height of the body above the plane of the film PP', H the predetermined height of the center of the target above the same plane. $(H - h)$ is the

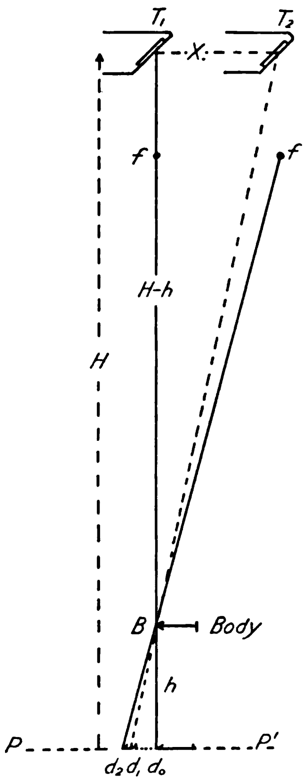
height of the center of the target above the body, X the predetermined displacement of the target resulting in the displacement of the second shadow from d_0 to d_2. Geometrically speaking, if the source of the energy is a point lying in the face of the target at T_1 displaced to T_2, then the shadow cast by the arrow-head of the body will be displaced from d_0 to d_1. The height of the body above the plane is then $h = Hd/(X + d)$.

This is the relation used in all literature describing localization methods and does not take into consideration a variable of prime importance, namely, that the point T_2 is not the origin of the rays casting the shadow of the body in the plane PP'. The measured shadow extends from d_0 to d_2 while the predicted geometrical shadow only extends from d_0 to d_1. The origin of the point d_2 does not lie at T_2 but at f' below the target. Previous methods tacitly assume that the X-ray beam is a geometrical cone of energy of small numerical aperture with its apex lying in the center of the face of the target T. As a matter of fact this is only a very close approximation in a very fine focus tube, a tube with a small focal spot and with very uniform energy distribution over its surface.

The design of the Coolidge tube is such as to make the filament emit a tubular beam of electrons with minimum intensity at the outer and inner periphery of the tube. A pinhole camera image of the X-ray beam will show what is the distribution of energy over its surface. Except in case of a very sharp focus tube this energy distribution will give focal spot images of shapes comparable to balloon tires which are slightly elongated along a line lying parallel to the axis of the tube. To visualize the conditions let us refer to Fig. 2. The electron stream as here shown is concentrated near the outer boundary with relatively few at the center of the stream. This is due to the higher temperature on the periphery of the spiral heater element. The generated X-ray energy is hence principally confined to the area roughly indicated by the arrows at "a" and "b." If these areas are now reproduced through the pinhole in the form of a point for point image in the plane PP', we see how the balloon tire shape photographic image is generated by the overlapping of the

various beams originating at the areas "a" and "b." The broader the focus of the tube the more pronounced the distortion of this area in the plane PP'. It will be noticed however that geometrically a virtual focus exists at f_a due to the crossing of the beams generated by the area "a" and a corresponding virtual focus at f_b due to the area "b." So that on the average a virtual focus $(f_a + f_b)/2 = f$ lies

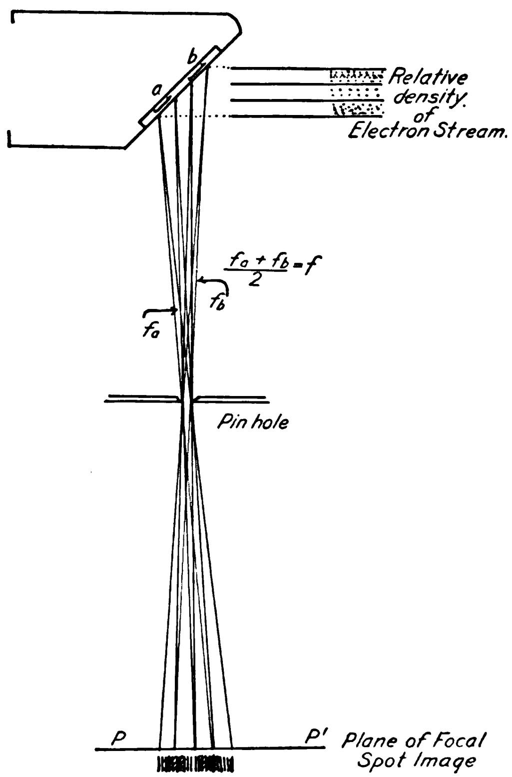
FIG. 1.



below the center of the target. This virtual focus may be considered as acting like a point source, sending out a conical pencil of X-ray energy effecting the plate PP' in the usual way. Interposing an opaque body B (Fig. 1) into such a beam of energy allows us to arrive at the geometrical size of the shadow in the plane PP' as d_0d_2 and not as d_0d_1 as the

simple geometrical analysis would predict, since the horizontal displacement of the target from T_1 to T_2 really displaces the virtual focus from f to f', where f', and not T_2, acts as the source to cast the shadow d_0d_2.

FIG. 2.



In order to determine the location of the virtual focus f, all one needs to do is to locate the apex of the cone forming the image PP' as in Fig. 2. These data are furnished by the diameter of the focal spot image PP', position and size of pinhole and position of target with respect to the plane PP'.

With a very sharp focus tube no appreciable error is introduced in the value of h, the height of the foreign body above the plane, by assuming that f merges into the face of the target.

In other words, the shifting of the target through a horizontal distance X will lead to a shadow shift d_0d_1 but not to the observed shift d_0d_2. This shift of the target is, however, equal to the horizontal shift X of the virtual focus f to f' leading to a geometrical ray connecting f' to B and intersecting the shadow at the expected point d_2. (Fig. 1.)

Allowing for this correction we find that the height of the body above the plane PP' is now given by $h = d(H - f)/(X + d)$, where all the letters have the same significance as in Fig. 1 and f is the distance of the virtual focus below the center of the target and d the measured shadow displacement d_0d_2 as taken from the plate.

One naturally inquires as to the practical value of such discriminations. An example of the results obtainable with and without this focal correction using a medium broad focus Coolidge tube is shown in Table I.

TABLE I.

d	h	h_2	h_1
.39	4.1	4.24	4.67
.66	7.1	6.92	7.59
1.00	10.3	10.0	11.0
1.76	16.2	16.0	17.6

A lead plate 3 mm. thick with a sharp edged slot cut into it 6×0.3 cm. was used as a foreign body. It was placed in a horizontal plane at a distance "d" cm. above the plane of a photographic film which was inclosed in a cardboard cassette. The center of the target of the Coolidge tube was set at 82.5 cm. above the film and displaced in each observation 6.5 cm. The displacement of the shadow was measured by means of a pair of drawing instrument dividers to the nearest tenth of a millimeter. The height "h" of the foreign body (the slot) above the plane of the film was then computed, first uncorrected for virtual focus as $h_1 = dH/(X + d)$ and, second, corrected for virtual focus as $h_2 = d(H - f)/(X + d)$. It is obvious that the corrected values in Table I represented by the column h_2 are 10 per cent. nearer the true values of "h" than those computed from the uncorrected formula. The values of h_2 show on an average only a 2 mm. departure

from their true predetermined values. Accurate results are thus obtained comparable to very elaborate technique aided by a very fine focus tube.

In general the broader the focal spot of the tube the greater the error of localization if the target is taken as the source of the X-radiation. The error may, however, be reduced to a minimum if the position of the virtual geometrical focus existing below the target is used instead of the center of the target as the height of the source producing the displaced shadows. Thus a medium or broad focus tube can be used in general practice where the frequency of the demand for this particular type of technique does not warrant the purchase of an additional fine focus tube.

In view of the fact that probably no two Coolidge tubes have the same type of focal spot with identical energy distribution over its area it follows that the position of the virtual focus for every tube must be experimentally determined.

The procedure for determining the geometrical position of the virtual focus is as follows:

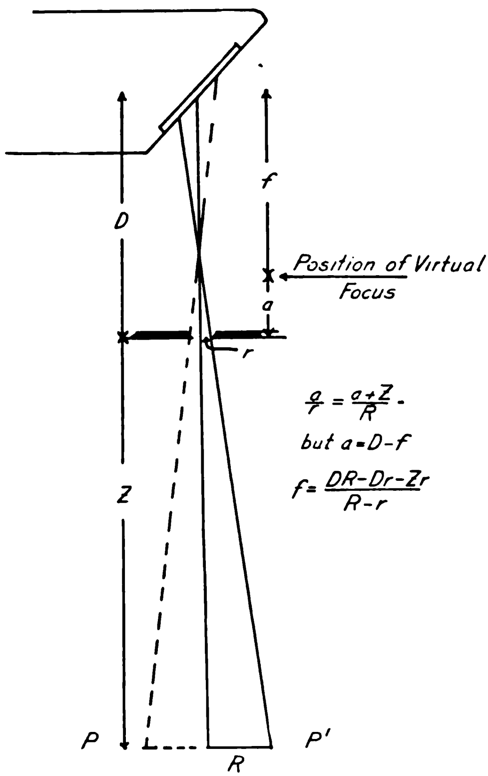
Make four or more focal spot pictures on a single film as outlined in the "Instruction Book for Coolidge X-Ray Tubes" as issued by the General Electric Co., of Schenectady, N. Y. If this is not available the following summary will suffice.

"Take a small sheet of lead, say 3 mm. (1/8 inch) thick and of the right size to take the place usually occupied by the diaphragm in the cone of the tube holder. Make a conical depression in the center with a machinist's prick punch or other blunt nosed tool and then with a small drill, open the hole at the bottom of the depression to a diameter of about 1 mm. With the lead plate in place, measure the distance from the center of the target to the pinhole directly below it. This measurement must be made to 2 mm. (1/16 inch). Place a film at some known distances below the pinhole, say 15, 20, 25 and 30 cm. Since the size of the focal spot image at any given distance is always the same regardless of the current and voltage employed, a long time exposure will show the full extent of the focal spot and a short exposure the distribution of the energy over it." The

developed image on the film will resemble a slightly distorted perspective of an automobile balloon tire.

For each of the above images measure the mean outer diameters. Lay off to scale these dimensions as shown in Fig. 2. First lay off the inner and outer diameters of the image in the plane PP' formed by placing the pinhole 15 cm.

FIG. 3.



above the plate. Erect a perpendicular 15 cm. to the position of the 2 mm. pinhole. Then place above the pinhole the 45° tungsten target at the predetermined distance from the pinhole to center of target.

Reproduce the focal spot image point for point as originating first from the lower third of the target and then from the upper third of the target as at "*a*" and "*b*." The

intersection of the lines show graphically the location of the virtual foci marked f_a and f_b. The mean distance $(f_a + f_b)/2 = f$ of these two foci is here considered as the location of the virtual focus associated with the tube. It will be noticed that the distortion of the focal spot in a direction along the axis of the tube is produced by the 45° slope of the target.

By using the predetermined positions and the data obtained from the above focal spot determinations it is perhaps simpler and more satisfactory to compute the position of the virtual focus from a diagram similar to that shown in Fig. 3. Here "D" is the distance between the lower face of the lead plate containing the pinhole of radius "r" and the target "Z" the height of the lower face of the pinhole plate from the upper surface of the photographic film in the plane PP' producing a pinhole image of outer radius R. If "f" is the distance of the virtual focus below the center of the target and "a" the distance of this focus above the pinhole, then focal length

$$f = \frac{DR - Dr - Zr}{R - r}.$$

To illustrate the reproducibility of the resulting values of f as applied to a medium broad focus tube, set the latter with its target 8.8 cm. above the pinhole and at various heights Z above the plane of the film. The resulting data are given in Table II.

TABLE II.

D	Z	r	R	f
8.8	14.2	.05	.59	7.49
8.8	17.2	.05	.685	7.46
8.8	21.2	.05	.85	7.47
8.8	24.2	.05	.95	7.46
			mean $f = 7.5$	

The diameter of the pinhole was 1 mm. The images of the focal spots obtained at various distances Z had external radii whose values are indicated by the column marked R. The focal distances as computed from the above data are given in the column marked f. The mean value thus obtained

is a fair representation of the accuracy of the method employed.

In the case of a small focal spot the central circular area of the focal spot image shrinks to a negligible diameter. If, in addition, the electron stream is of uniform density then the distance from the target to the virtual focus becomes negligibly small and the focus may for all practical purposes be considered as located at the surface of the target.

The data for this discussion were obtained by G. W. Heinitsh and J. E. Morris.

THE UNIVERSITY OF NORTH CAROLINA,
CHAPEL HILL, N. C.

Electrical Methods of Hygrometry. P. W. BURBIDGE AND N. S. ALEXANDER. (*Proc. Phys. Soc.*, London, vol. 40, Pt. 3, 1928.) It is surprising that the extension of scientific research and the development of methods of measurement have done so little for hygrometry. There remain the three standard ways of determining the humidity of the air, by the wet and dry bulb thermometers, by the dew point and by the change of length of a hair. Not one of them can rival in accuracy and convenience the methods used to measure other far less obvious and less practically important quantities. This paper gives an account of an effort to devise better means of measurement. Pure cotton wool was placed between two electrodes placed in a box containing the air of which the humidity was to be determined. No polarization showed itself and Ohm's Law was followed. The electrical resistance for different relative humidities was measured, the temperature being constant. On plotting the logarithm of the resistance against the relative humidity a straight line was obtained. "At high humidities the resistance decreased enormously, and trustworthy readings could not be obtained above 95 per cent. humidity." Besides this the time lag was excessive. By an improved arrangement the lag was reduced to 5 or 6 minutes. The resistance of human hair freed from grease also was measured. When the relative humidity varied from 0 to 50 per cent. the change in resistance was rather small. It was greater for higher humidities.

A further endeavor was made to correlate humidity with the mobility of ions in air. Tyndall and Grindley had shown that the mobility of negative ions sinks from 2.15 in dry air to 1.6 in air saturated with water vapor. Here again failure was encountered. It is a promising sign that physicists are working upon the problem of measuring humidity. Recognized problems have a way of becoming solved.

G. F. S.

AN EXPERIMENTAL INVESTIGATION OF FORCED VIBRATIONS.

BY

L. W. BLAU, M.A.

Abstract.

The solution of the differential equation $y'' + 2Ry' + n^2y = E \cos pt$ is written in a new form which clearly exhibits many important facts thus far overlooked by theoretical and experimental investigators. Writing $s = n - p$, and $\Delta n = n - \sqrt{n^2 - R^2}$, it is found: (*a*) When $s \neq \Delta n$, there are "beats," and the first "beat" maximum is greater than any later maximum while the first "beat" minimum is less than any later "beat" minimum. The "beat" frequency is $(s - \Delta n)/2\pi$. (*b*) When $n^2 - p^2 = R^2$, there are no "beats," and the resultant amplitude grows monotonically from zero to the amplitude of the forced vibration, (*c*) At resonance, when $n = p$, we still have maxima which occur with a frequency $\Delta n/2\pi$ in a damped system. (*d*) The absence of "beats" is neither a sufficient nor a necessary condition for resonance in a damped system.

In the experimental investigation the upper extremity of a simple pendulum was moved in simple harmonic motion and photographic records obtained of the motion of the pendulum bob. Different degrees of damping were used, ranging from very small to critical.

The experimental results are in excellent agreement with theory.

1. INTRODUCTION.

THE subject of forced vibrations has been investigated rather fully, both mathematically [1] and experimentally,[2] but neither the relations derived mathematically nor the experimental results exhibit clearly the principal facts of this type of motion. In the following pages an equation derived and published elsewhere [3] is employed, and an experimental arrangement is described which permits of the investigation of forced vibrations. Photographic records are shown which verify the theoretical results.

[1] Rayleigh, "Theory of Sound," 2d Ed., Macmillan, 1894. Duffing, "Erzwungene Schwingungen bei veraenderlicher Eigenfrequenz und ihre technische Bedeutung," F. Vieweg u. Sohn, Braunschweig, 1918. Riemann-Weber, "Die Differential- und Integralgleichungen der Mechanik und Physik, zweiter, physikalischer Teil, F. Vieweg u. Sohn, Braunschweig, 1927, pp. 86 ff.

[2] Barton and Browning, *Phil. Mag.*, 36, pp. 169–178, 1918.

[3] *The American Mathematical Monthly*, 35, June–July, 1928.

2. THEORY.

In the paper referred to above [3] the differential equation of forced vibrations was written

$$\ddot{y} + 2R\dot{y} + n^2 y = E \cos pt, \tag{1}$$

where y = displacement from the position of rest,

R = damping factor,

$\frac{n}{2\pi}$ = natural frequency of the vibrating system

and $\frac{p}{2\pi}$ = frequency of the impressed force.

The general solution of (1), for the case when R^2 is less than n^2, is

$$y(t) = A \cos pt + B \sin pt + Ce^{-Rt} \cos \sqrt{n^2 - R^2}t + De^{-Rt} \sin \sqrt{n^2 - R^2}t,$$

where

$$A = \frac{(n^2 - p^2)E}{(n^2 - p^2)^2 + 4R^2p^2} \tag{2}$$

and

$$B = \frac{2RpE}{(n^2 - p^2)^2 + 4R^2p^2}.$$

If we now impose the initial conditions

$$y(0) = 0; \qquad \dot{y}(0) = 0,$$

that is, that the initial displacement and the initial velocity are each equal to zero, then the constants C and D in (2) must have the following values:

$$C = \frac{-(p^2 - n^2)E}{(n^2 - p^2)^2 + 4R^2p^2},$$

$$D = \frac{-RE(n^2 + p^2)}{\sqrt{n^2 - R^2}\,[(n^2 - p^2)^2 + 4R^2p^2]}. \tag{4}$$

I have shown recently [3] that equation (2) may be written

$$
\begin{aligned}
y(t) = \Bigg\{ & A^2+B^2+(C^2+D^2)e^{-Rt} \\
& -2e^{-Rt}\sqrt{(A^2+B^2)(C^2+D^2)}\,\sin\Big[(s-\Delta n)t \\
& +\tan^{-1}\frac{C}{D}+\tan^{-1}\frac{B}{A}\Big]\Bigg\}^{\frac{1}{2}} \qquad (5) \\
& \times\left(\sin pt+\tan^{-1}\frac{A+e^{-Rt}\sqrt{C^2+D^2}\,\sin\left[\Delta nt+\tan^{-1}\dfrac{D}{C}\right]}{B+e^{-Rt}\sqrt{C^2+D^2}\,\cos\left[\Delta nt+\tan^{-1}\dfrac{C}{D}\right]}\right),
\end{aligned}
$$

where $s = n - p$, and

$$\Delta n = n - \sqrt{n^2 - R^2}.$$

If we take the differential equation

$$\ddot{y} + 2R\dot{y} + n^2 y = E \sin pt, \qquad (6)$$

which applies to the case of forced vibrations investigated experimentally by the writer, subject to the conditions (3), the solution may be written in the form (5), but the constants will then have the following values:

$$
\begin{aligned}
A &= \frac{-\,2RpE}{(n^2 - p^2)^2 + 4R^2p^2}, \\
B &= \frac{(n^2 - p^2)E}{(n^2 - p^2)^2 + 4R^2p^2}, \\
C &= \frac{2RpE}{(n^2 - p^2)^2 + 4R^2p^2} \qquad \text{and} \qquad\qquad (7) \\
D &= \frac{E(2R^2p - n^2 + p^2)}{\sqrt{n^2 - R^2}[(n^2 - p^2)^2 + 4R^2p^2]}.
\end{aligned}
$$

Equation (5) is better adapted to the investigation of the resultant displacement than equation (2). We make note of the following facts from the expression for the amplitude of the resultant displacement and from the phase angle as given by (5):

1. When s is different from Δn, there are "beats," forming a regularly spaced array of maxima and minima, and the first

"beat" maximum is greater than any later maximum, while the first minimum occurring after $t = 0$ is smaller than any later minimum. It is to be noted that the frequency of these "beats" is $\dfrac{s - \Delta n}{2\pi}$. Hence, in a damped system under forcing, the "beat" frequency is not equal to the difference between the frequencies. True beats are given by damped systems only when the vibrations of the systems are separately maintained.

2. When $n^2 - p^2 = R^2$, there are no "beats," and the resultant amplitude grows monotonically from zero to the amplitude of the forced vibration in the steady state. The difference between the squares of the frequencies in this special case has been called the critical frequency-difference. Only when this condition is satisfied is it true that "While the free vibration is dying away, the resultant motion which is under observation grows from nothing to the fixed amplitude and phase of the forced vibration." [4]

3. When $n = p$, we still have maxima which occur with a frequency $\dfrac{\Delta n}{2\pi}$ in a damped system. The solution (5) of equation (6) satisfying (3) then reduces to

$$y(t) = \frac{E}{2Rn}\left\{ 1 + \left(\frac{n^2 - R^2 + 1}{n^2 - R^2}\right)e^{-2Rt} - 2e^{-Rt}\sqrt{\frac{n^2 - R^2 + 1}{n^2 - R^2}}\sin \times \left[\tan^{-1}\sqrt{n^2 - R^2} - \Delta nt\right]\right\}^{\frac{1}{2}} \sin(nt + \alpha),$$

where

$$\alpha = \tan^{-1}\frac{-1 + \sqrt{\dfrac{n^2 - R^2 + 1}{n^2 - R^2}}\,e^{-Rt}\sin \times \left[\Delta nt + \tan^{-1}\sqrt{n^2 - R^2}\right]}{\sqrt{\dfrac{n^2 - R^2 + 1}{n^2 - R^2}}\,e^{-Rt}\cos\left[\Delta nt + \tan^{-1}\sqrt{n^2 - R^2}\right]}.$$

[4] Barton and Browning, "*Phil. Mag.*," 36, p. 171, 1918.

If the damping is small, the "beat" maxima occur at a comparatively late time, that is, when the free vibration has nearly died away. If the damping is large, however, these "beat" maxima occur for small values of t and should therefore be observable. Calculation shows that even though, with large damping, the free vibration decays more quickly, the maxima occur at such an early stage that the amplitude of the resultant motion is appreciably greater than the amplitude of the forced vibration in the steady state. With large damping, that is, nearly equal to, or greater than, the critical, the first maximum occurs on the first outward excursion of a mechanical system. We can not very well call these maxima "beats," although they are in every way, except in their origin, the same as "beats" and can not be distinguished from them. Beats, in the generally accepted sense of the word, are possible only in an undamped system under forcing or in systems of which the vibrations are separately maintained. The pseudo-beats observed in a damped system under forcing may have a greater or a smaller frequency than the difference between the impressed and the natural frequencies depending upon whether s is negative or positive, that is, on whether the impressed frequency is greater or smaller than the natural frequency of the system.

4. In all cases where there is damping and where s is different from Δn, the first "beat" maximum is greater than any of the later relative maxima and greater than the amplitude of the forced vibration in the steady state, while the first minimum is smaller than any later relative minimum; the maxima decrease, while the minima increase, to the amplitude of the steady state vibration.

The absence of beats is neither a sufficient nor a necessary condition for resonance in a damped system; when there are no beats this simply means that the difference between the squares of the frequencies has the critical value.

3. EXPERIMENTAL ARRANGEMENT.

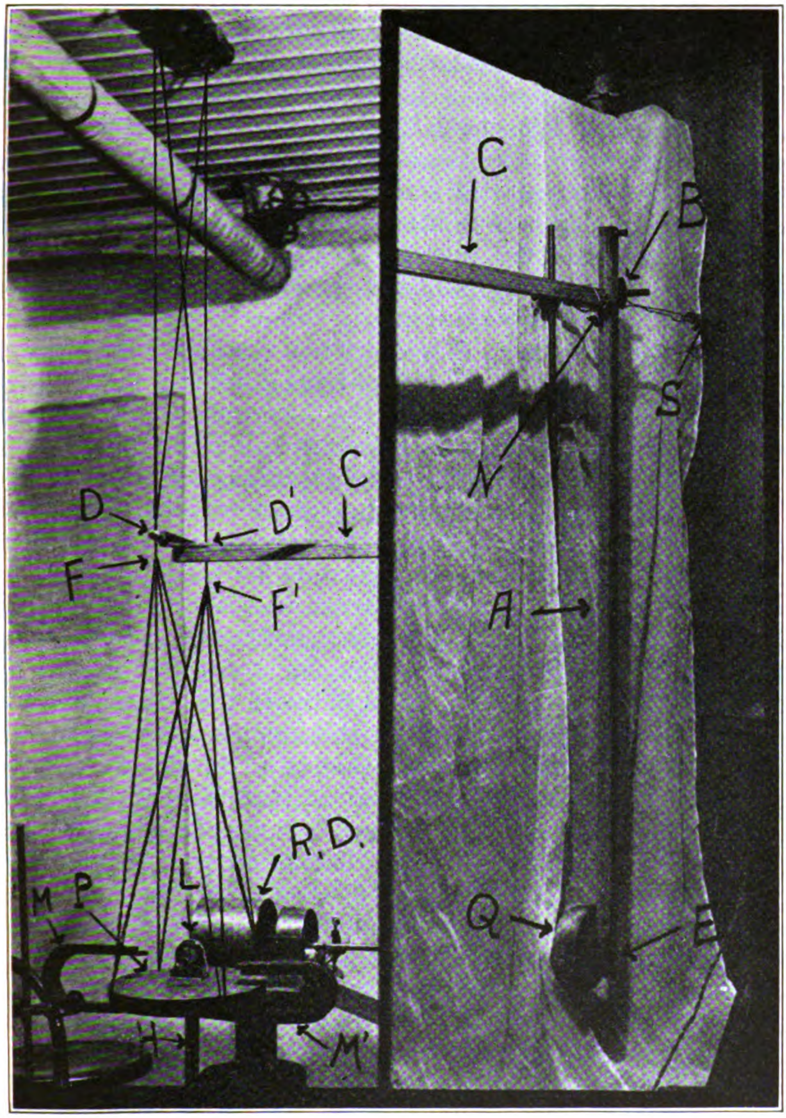
(*a*) *Small Damping:* The experimental arrangement is shown in the photograph, Plate I. A lead disc P weighing about 46 pounds was suspended from the ceiling by means of two piano wires. At the points F and F' three other wires

were soldered to these suspensions and secured to the bob as shown in the photograph to assure as great rigidity and freedom from torsional motion as possible. A photographic objective L was placed on the bob, and the light from a distant pin-hole source focused on a rotating drum $R.D$ carrying the photographic paper. This drum was set with its axis parallel to the direction of motion of the pendulum. In this manner the spot of light traversed the paper with the motion of the pendulum. A cross-piece was secured between the suspension wires at the points D and D'. Then a stick of wood C one inch square and 6.5 feet long was secured to this cross-piece and fastened by means of a brace at right angles to it. The other end of the stick C was provided with a brass knife-edge which rested in a slot N screwed to a vertical connecting rod A four feet long. The lower end of the rod A was fastened to an adjustable-eccentric bearing E in a large wooden pulley Q, while the upper end rested against a steel pulley B which permitted of adjustment in a vertical direction. The stick C was held in position against the connecting rod A by a coiled spring S secured to the wall of the room. The pulley Q was driven through appropriate pulleys and counter shaft by a one-eighth horsepower, 110 volt, direct-current motor. The motor derived its power from a bank of storage batteries, its speed being regulated by a rheostat.

It was found that the pendulum was insufficiently damped, the time required to reach the steady state being upward of an hour. Two horseshoe magnets M and M' were then placed one on each side of the pendulum bob, so that the latter oscillated between the poles of the magnets.

It is perhaps not immediately evident that with the arrangement as described and illustrated the upper extremity of the effective pendulum at D could be moved in simple harmonic motion as required by the theory. It is true that a point on a connecting rod does not execute simple harmonic motion; however, when it is remembered that the distance EN was 93 cm. (3 ft.), that the vertical distance from N to the horizontal through the center of the pulley B was never more than 15 cm., that the eccentricity of E had to be so small that the amplitude impressed at D was never greater than 0.5 millimeters and as small as approximately 0.01

PLATE I.



View of the experimental arrangement.

millimeters in this part of the experiment, there can be no valid objection to the arrangement.

Considerable difficulty was at first experienced in keeping the motor running at uniform speed. When first connected the speed of the motor was found to increase due to the rise in temperature. Whenever the batteries were connected to other apparatus in the laboratories the speed changed. By operating the motor for at least two hours before taking any records, by making sure that the batteries were not connected anywhere else, and by working at night when temperature changes were less likely to occur, the speed of the motor was finally kept sufficiently constant.

(*b*) *Large Damping:* The lead bob described above was found to be too heavy to permit of large damping. A wooden disc was then substituted for the heavy bob. A quarter inch copper plate, sixteen inches long and eight inches wide was secured to this disc in a vertical position and an electromagnet placed so that the copper plate oscillated between the pole pieces. The weight of the bob was then only eight pounds, and the damping factor could be made as large as desired. The optical arrangement was also changed by connecting an optical lever to the pendulum and focusing the light from the pinhole source on a rotating drum by means of a long-focus lens placed between the source and the mirror on the optical lever. In this manner it was possible to secure such magnification that the amplitude of the impressed force could be reduced to such a value that the pendulum never oscillated with an amplitude greater than 3 mm. The prevention of larger displacements was necessary on account of the fact that with large damping and a lighter bob the instantaneous axis of oscillation of the pendulum shifted to a point considerably below the top of the effective pendulum, thus causing a rocking motion of the bob which was objectionable. With small oscillations of the pendulum this rocking was negligible.

In this part of the work the requirements as to steadiness of the motor were not nearly as stringent as when the damping was small, and no difficulty was experienced. Different degrees of damping were secured by inserting suitable resistances in the circuit of the electromagnet.

4. EXPERIMENTAL RESULTS.

(*a*) *Small Damping:* Figures Nos. 1–18 inclusively are records of the motion of the pendulum bob under the influence of an impressed periodic force, the bob having been at rest at the beginning. In order to facilitate bringing the pendulum to rest and also to assure its being at rest when a record was started, a strap of brass *H* 3 mm. thick, 25 mm. wide and 30 cm. long was fastened in a vertical position to the lower side of the bob. A can filled with heavy oil was placed on a stool under the bob in such a manner that the oil can could be raised or lowered without disturbing the pendulum. Before starting a record the oil can was raised, immersing the brass strap in the oil to a depth of about five inches and thus bringing the pendulum to rest. When, after a few minutes, this had been accomplished, the can was lowered until the brass strap no longer dipped into the oil. A strip of photographic paper was then placed on the rotating drum and the motor connected with the system. As indicated above, the motor was never stopped between records, because, even if stopped for a very short time only, there was a slight cooling off, and consequent erratic speed.

The natural period of the pendulum was 1.708 seconds. In obtaining records Nos. 1–9 the period of the impressed force was greater than this natural period; the period of the impressed force was increased each time a new record was started. It is to be noted that the "beats" are longer on each record after the first than on the preceding record. The amplitudes also increase as resonance is approached, but the increase is much less than it would have been if the amplitude of the impressed force had been the same. As resonance was approached it became necessary to reduce this amplitude in order to keep the displacement of the pendulum sufficiently small to permit of recording, and also to prevent a change of the period and consequent error. In taking record No. 8 the amplitude was reduced to the order of 0.01 millimeters. The impressed amplitude was smaller on this record than on No. 10. Each record represents a run of approximately forty-five minutes. On No. 1 the impressed period was 1.678 seconds. As seen from No. 9, there was only one "beat" in about forty minutes.

FIG. 1.

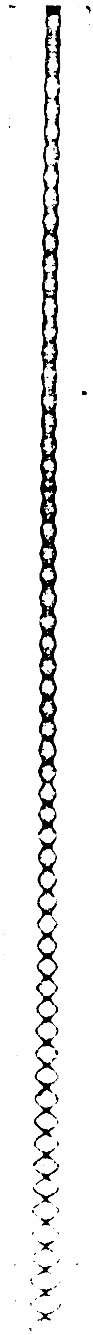


FIG. 2.

FIG. 3.

FIG. 4.

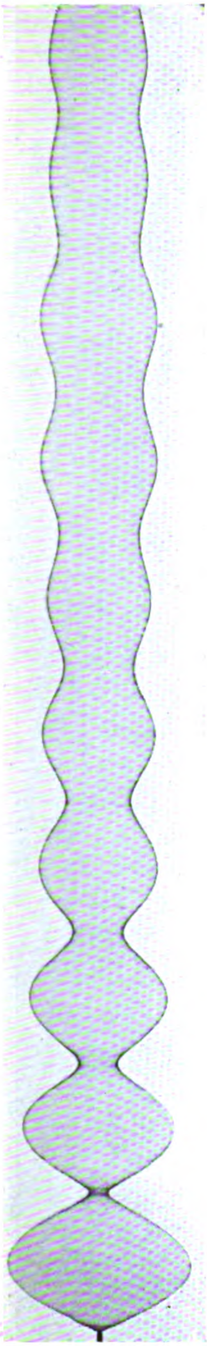


FIG. 5.

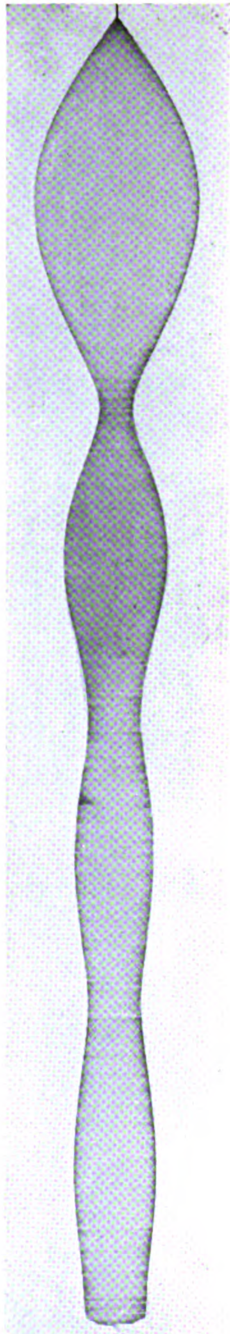


FIG. 6.

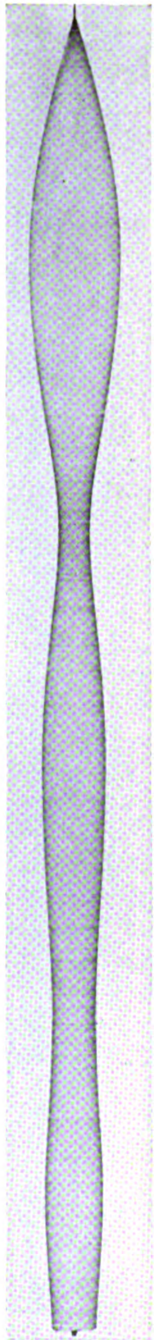


FIG. 7.

Fig. 8.

Fig. 9.

Fig. 10.

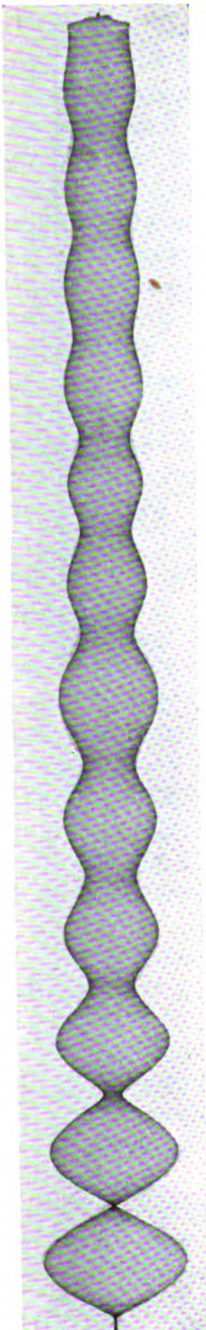


FIG. 11.

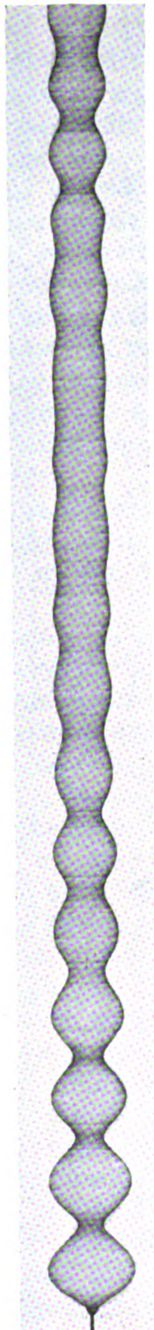


FIG. 12.

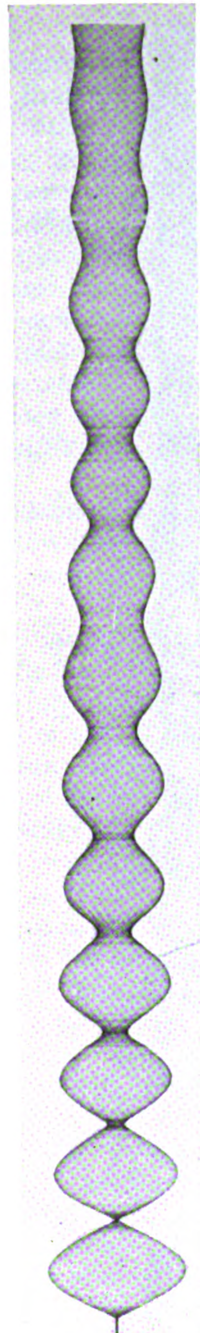


FIG. 13.

Fig. 14.

Fig. 15.

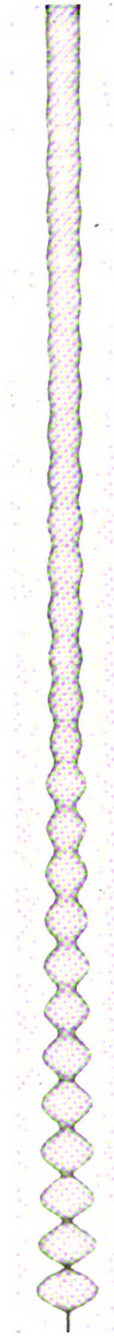


Fig. 16.

Fig. 17.

Fig. 18.

Record No. 10 shows the resultant displacement at, or very near, resonance. It is to be regretted that this record is not done as well photographically as the others, but for some unexplained reason the light was less intense while this record was being run, necessitating excessively long development and resulting in a fogged print. Many attempts were made to obtain another such record, but in vain; it was rather fortunate and somewhat accidental that the speed of the motor could be adjusted to maintain such remarkable constancy and, as near as one can tell, complete resonance. However, since the damping factor R was small, namely 0.0015, it is possible that there was a difference between the frequencies, namely the critical frequency-difference, mentioned under 2 above.

In records Nos. 11–18 the impressed frequency was still further reduced, being about as much below the natural frequency of the pendulum in No. 18 as it was above this frequency in No. 2.

The agreement with theory is truly remarkable. The first "beat" maximum is always the largest, the first minimum always the smallest. The amplitude of the forced vibration is always less than the maximum amplitude of the "beats."

In record No. 19 the pendulum was again started from rest. The speed of the motor, the amplitude of the impressed force and the damping were the same for this and the following three records. In Nos. 20, 21, and 22 different initial conditions were imposed. In each case the pendulum was caused to oscillate freely as shown at the beginning of each record. In 20 the motor was connected when the pendulum was swinging out on the right, in 21 when it was stopping at the right and in 22 when it was swinging in toward the left on the same side. There is apparently very little difference in these three records. We notice, however, that the minima in No. 20 decrease very nearly as a continuation of the decay curve of the undisturbed pendulum. In 21 the first minimum is somewhat lower than the decay curve, while the first minimum in 22 is still lower. The first maximum is greatest in No. 21, and least in 22. Remembering that the initial displacement was positive, although not exactly the same, in all three cases, that the initial velocity

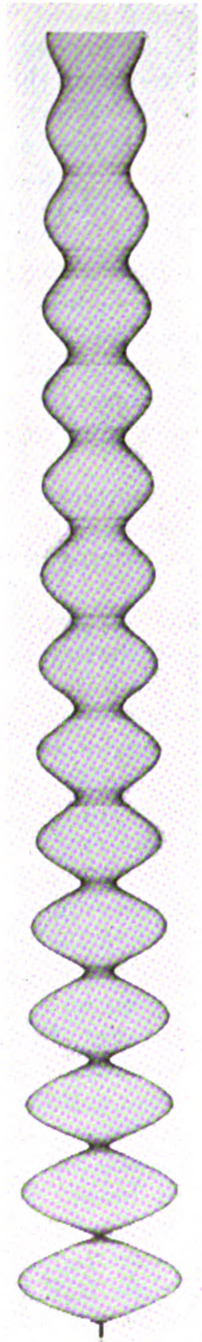


Fig. 19.

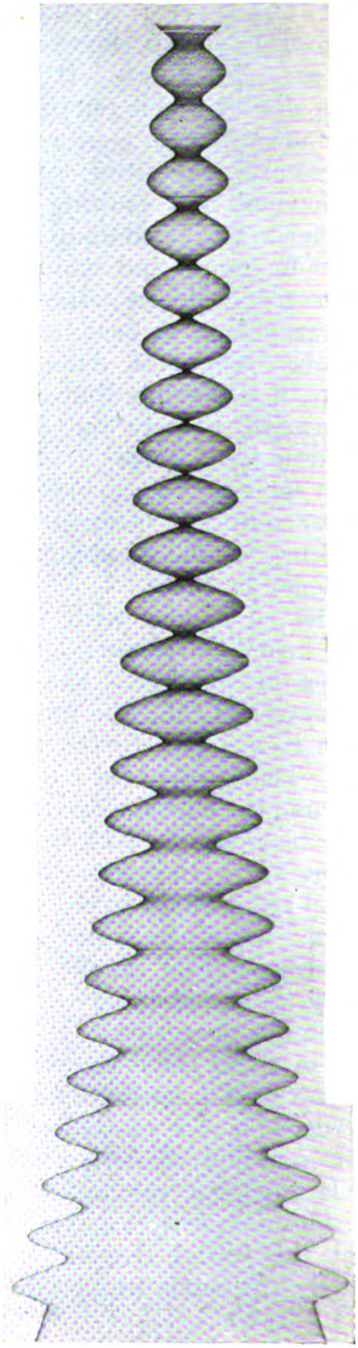


Fig. 20.

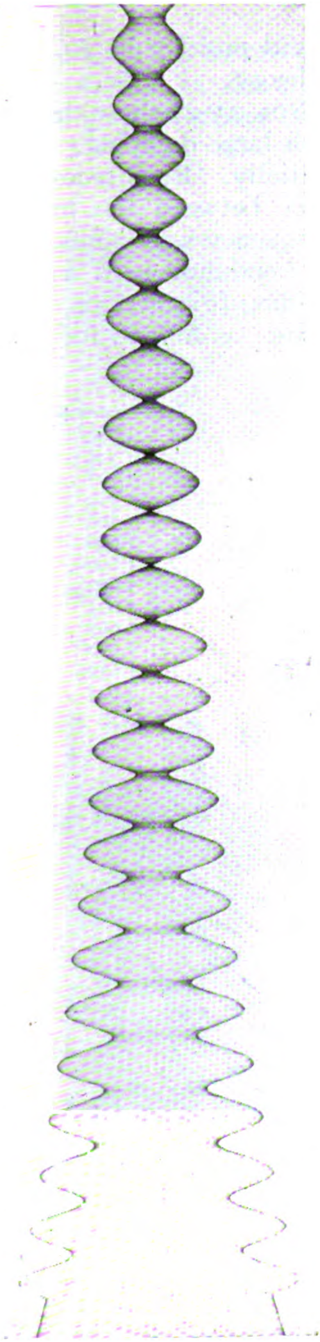


FIG. 21.

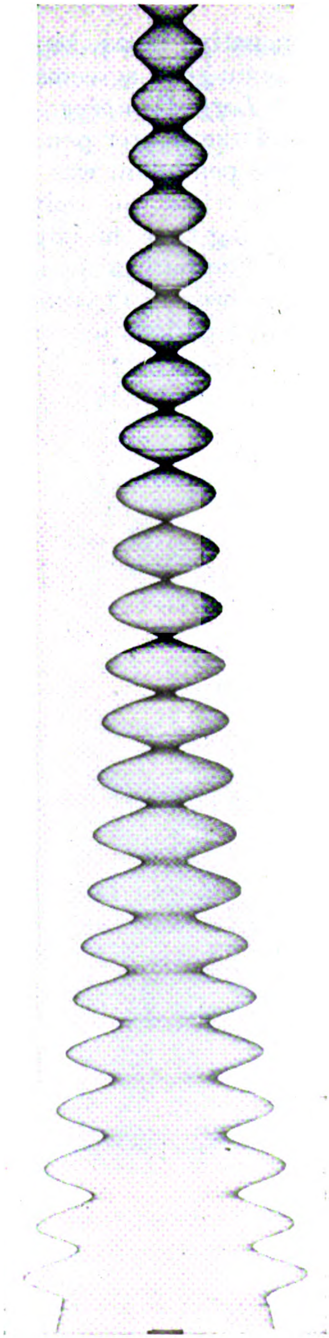


FIG. 22.

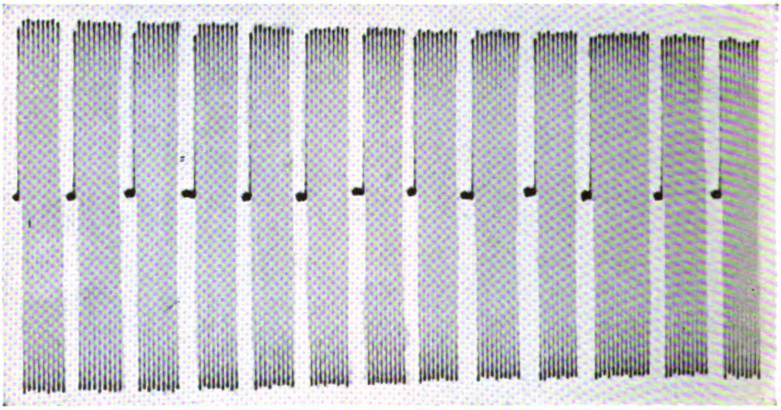
was negative in 22, zero in 21, and positive in 20, we find here again good agreement with theory.

(*b*) *Large Damping:* Records Nos. 23–27 show the oscillations of the lighter pendulum with large damping. In each case the pendulum was at rest initially. Each record shows thirteen trials, the only difference between the individual trials being that the impressed frequency was increased each time. The natural period of the pendulum used with large damping was 1.713 seconds. Reading from left to right the impressed periods for each trial were as follows for the five records Nos. 23–27:

TABLE I.

Trial	Periods (seconds)
1	1.739
2	1.730
3	1.721
4	1.713
5	1.706
6	1.698
7	1.690
8	1.683
9	1.675
10	1.667
11	1.660
12	1.652
13	1.644

FIG. 23.



It is apparent from the table that trial four in each case shows complete resonance; however, with the large damping used, the resonance curve is very flat, and hence all thirteen

trials approximate to resonance. Record No. 23 shows the resultant motion of the pendulum when the damping was such as to give the decay curve shown in the left-hand record of 23*a*. The drum was rotated faster in 23*a* than in 23 in

FIG. 23*a*.

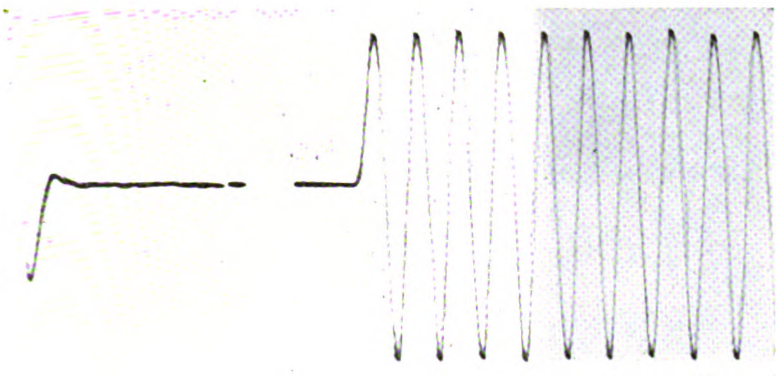
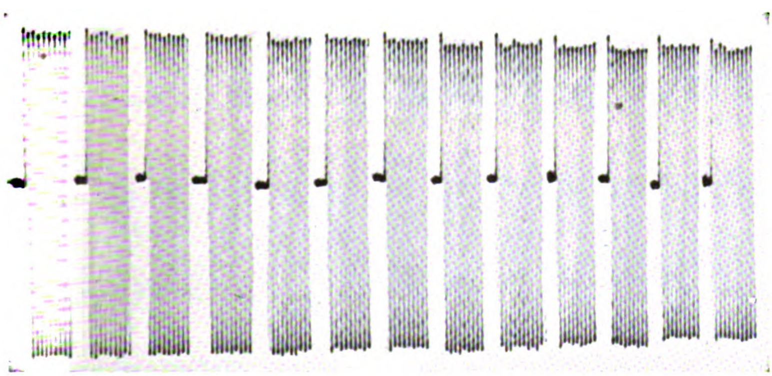


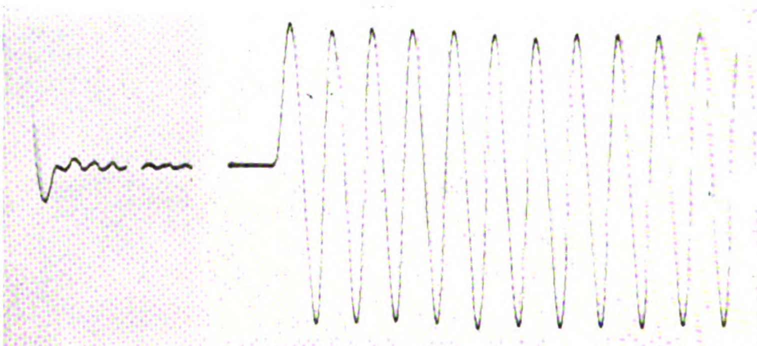
FIG. 24.



order to show better the decay curve and also, on the right-hand side, the change of phase at the beginning of the motion. When the damping is large the phase change is very rapid, being $-\frac{\pi}{2}$ in less than one period. As shown in 23*a* the drum moved forward a distance of 15 millimeters during the first complete vibration of the pendulum and 11 millimeters

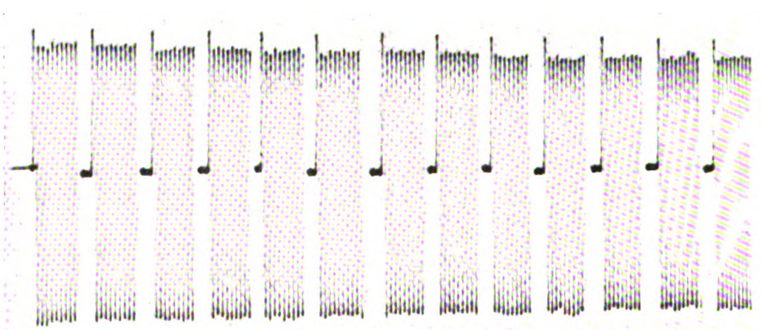
during any one complete vibration of the forced oscillations. The free vibration was practically damped out during the first period. It is to be noticed that with this damping the first outward excursion of the pendulum is less than the ampli-

FIG. 24a.



tude of the forced oscillations in the steady state; calculation shows that in this case the maxima are very little larger than the amplitude of the forced vibration, and they are for this reason not observable on this record.

FIG. 25.



In taking record No. 24 the damping was greater than in 23 as is shown by the decay curve on the left-hand side of 24*a*. The maximum in each trial shows up very clearly on the first swing as is required by theory.

FIG. 25a.

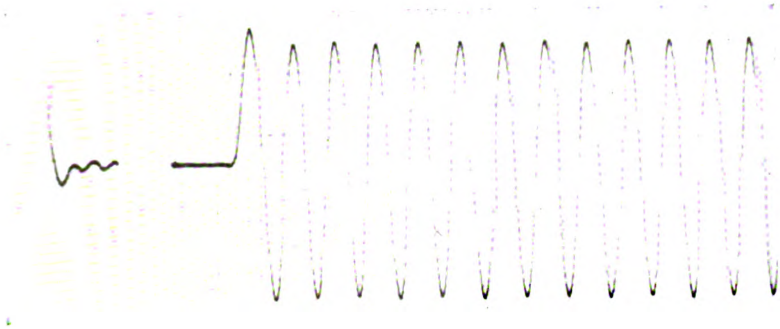


FIG. 26.

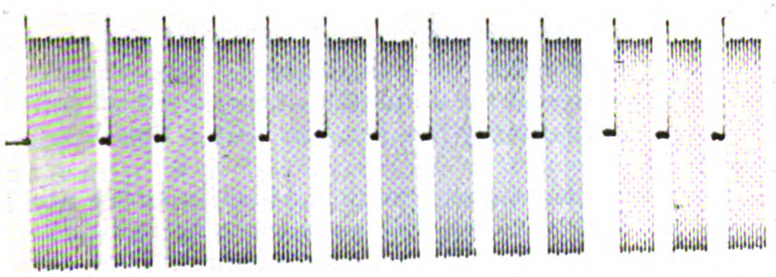
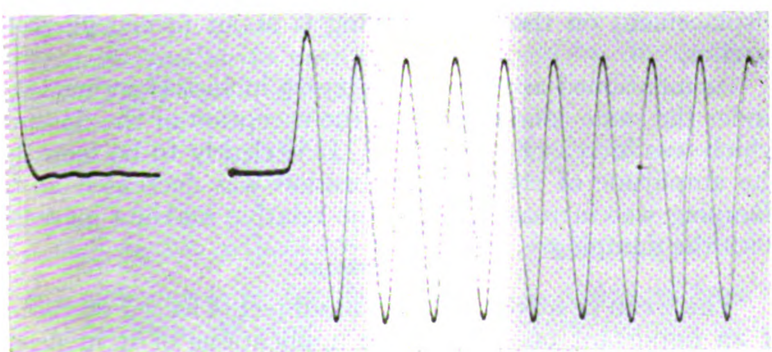
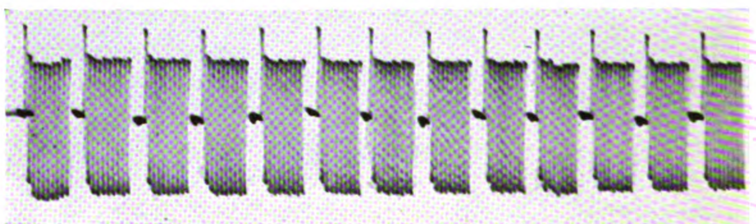


FIG. 26a.



Record No. 25 shows the resultant motion with still greater damping. The maxima are more prominent, being about 17/15 of the amplitude of the forced vibration. The right-hand side of 25*a* shows that the free vibrations were practically damped out in one-half of one period. The decay curve is shown on the left of record 25*a*.

FIG. 27.



The decay curve of record No. 26*a* shows that the damping was nearly critical when 26 was obtained. The maxima are still larger relative to the amplitude of the forced vibrations, being now about twenty-five per cent. larger than the later oscillations.

Another electromagnet was then added to secure greater damping. A decay curve which was taken but which is not reproduced shows that the damping was critical or greater than critical. Record No. 27 shows the displacements of the pendulum with this damping. The amplitude of the first swing of the pendulum is about thirty-five per cent. greater than the amplitude of the steady motion, while the displacement on the second swing is about fifteen per cent. smaller.

As mentioned above, records 23–27 inclusively were taken under the same conditions with the exception of the damping which was increased each time. It is clearly to be seen that the amplitude of the forced vibration was decreased as the damping was increased, while the relative maxima increased with the damping.

5. CONCLUSIONS.

There can be no doubt that the subject of forced vibrations is an important one; there are applications of it in nearly every branch of physics. One needs only to point out

mechanics, acoustics, optics, alternating currents in general and wireless telegraphy and telephony in particular. The subject has been investigated for a long time and has been incorporated into many textbooks dealing with differential equations and theoretical physics. The writer does not know of any intensive experimental investigations published before this; and it seems that all investigators, both theoretical and experimental, have entertained false notions about the subject. A statement by Barton and Browning to the effect that "While the free vibration is dying away, the resultant motion grows from nothing to the fixed amplitude and phase of the forced vibration" has been quoted earlier in this article. I have shown that this statement is true for one very special case only. Lord Rayleigh[5] writes: "During the coexistence of the two vibrations in the earlier part of the motion, the curious phenomenon of beats may occur, in case the two periods differ but slightly." Quite on the contrary, beats occur in every case (whether the difference between the frequencies be large or small) in which the difference between the squares of the frequencies is not equal to the square of the damping factor R; beats occur even at resonance in a damped system. The absence of beats proves conclusively that the two frequencies are different.

The first "beat" maximum is always the greatest, for at the beginning of the motion the free vibration is stronger than at any later time, while the amplitude of the forced vibration is constant. The first relative minimum occurring after the beginning is for the same reason the smallest minimum.

It is interesting to note the rôle played by the damping factor. The "beat" frequency s

$$\frac{s - \Delta n}{2\pi} = \frac{\sqrt{n^2 - R^2} - p}{2\pi}.$$

If R is zero this reduces to $\dfrac{n - p}{2\pi}$, and we have true beats. If R is different from zero and less than n, and if we have at the same time $R^2 \neq n^2 - p^2$, pseudo-beats always occur.

[5] "Theory of Sound," 2d ed., p. 50; Macmillan, 1894.

Hence there are "beats" even at resonance; this is amply illustrated by the results of the experiment. That the relative maxima should become larger with increasing damping seems, at first blush, strange. This is explained, however, by the change in phase which causes the period of the resultant vibration to be longer while the free vibration lasts. The rate of change of phase varies with the damping factor, the time required for the phase to become constant depending upon R and being less when R is large.

It has been shown that the oscillatory solution of the differential equation of forced vibrations should be written in the form (5) rather than in form (2) as generally given in textbooks, because the former solution exhibits more clearly the important facts. Failure to reduce the solution to form (5) has resulted in the overlooking, on the part of investigators, of many interesting facts regarding this type of motion. Physical intuition is not a sufficiently sure guide when the problem is to combine two or more oscillatory motions although, when once seen in an equation, everything shown by the mathematical solution permits of clear and simple physical interpretation.

I take pleasure in acknowledging my indebtedness to Professor Romberg for helpful suggestions.

PHYSICAL LABORATORY,
UNIVERSITY OF TEXAS,
AUSTIN, TEXAS,
March 26, 1928.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

BUREAU OF STANDARDS JOURNAL OF RESEARCH.

THERE has just been issued the first number of a new monthly periodical, the "Bureau of Standards Journal of Research." This journal continues the publication of the two series of research papers heretofore issued—"Scientific Papers" and "Technologic Papers." Forty-four volumes (22 of each of the two superseded series) have been published, comprising 942 research papers (572 on fundamental and 370 on applied science).

The new journal will contain the bureau's research papers and critical reviews in the fields of science and technology. These will be comparable in interest and importance with the scientific and technologic papers already issued. The union of pure and applied science in one journal will, it is believed tend to shorten the lag between discovery and its application.

Everyone engaged in scientific or technical work should have available for current use and permanent reference this new research journal. The paper page size is $5\frac{7}{8}$ x $9\frac{1}{8}$ inches, and each volume (semiannual) will be indexed. A cumulative consolidated index will be included in the bureau's list of publications as heretofore.

The subscription rate is $2.75 in the United States, Canada, Mexico, or Cuba, and $3.50 per year for other countries. The price of single copies is 25 cents domestic and 31 cents foreign. Remittances must be sent to the Superintendent of Documents, Government Printing Office, Washington, D. C., *not* to the Bureau of Standards.

Shortly after each month's *Journal* is published, reprints of the separate articles contained may be purchased from the Superintendent of Documents.

PHYSICAL PROPERTIES OF HEAVY CLAYS.

IN connection with the heavy clay investigation being conducted at the Columbus branch of the bureau, a series of

* Communicated by the Director.

experiments was carried out to ascertain the pressures required to extrude the several shales and clays through dies. The pressure required to cause continuous flow of the material through a die of ½ inch diameter was determined at four different percentages of tempering water for each of the shales and clays, the values being obtained for two different finenesses of grind, namely, as ground in a commercial 5 ft. dry pan, and as ground in a ball mill for about 16 hours after dry panning. The data were plotted into curves from which the extrusion pressures could be obtained at the water concentration previously found to be necessary for properly tempering when the small auger machine was used. These values are shown in the following table.

Attention is called to the fact that the ball-milled shale samples required considerably more pressure than the commercially ground samples, the values averaging 117.9 and 25.9 lbs./in.^{2} respectively when using the same percentages of water. This is to be expected, because with a marked increase in fineness of grain greater amounts of water are required for properly tempering. In the case of the glacial and alluvial clays, the effect of ball milling was not very clear-cut because of the extreme fineness of these clays even when commercially ground. However, in general, a decrease in grain size is accompanied by a decrease in extrusion pressure when properly tempered, this being probably due to lessened friction. This is shown by the fact that even when using the same percentages of water, the average pressures for the commercially ground and ball-milled glacial clays are 56.2 and 54.7, respectively. In the case of the alluvial clays, the average pressures for the commercially ground and ball milled samples are 85.1 and 82.4, respectively.

Slight variations in water content greatly affect the extrusion pressures. Thus, it is evident that in the industry great fluctuations in the power required for the pug mill and auger machine may be encountered by slight variations in the amount of tempering water employed and by the fineness of the grind. In general, alluvial clays require greater extrusion pressure than glacial clays, and shales require less than either of the clays, the average values being 90.5, 56.2, and 25.9 lbs./in.^{2} respectively.

Kind of Shale or Clay.		Pressure in Pounds per Square Inch Required to Extrude through a ½ Inch Diameter Die.	
		Commercial Grind.	Ball Milled.
Shales	Allegheney, Malvern	31.2	262.0
	Connemaugh, Ava	15.0	199.0
	Allegheney, New Lexington	20.0	76.5
	Waverly, Hanover	29.5	31.5
	Chagrin, Cleveland	17.0	41.2
	Waverly, Portsmouth	27.0	110.0
	Dunkard, Marietta	10.0	191.2
	Pottsville, Portsmouth	45.0	88.0
	Connemaugh, Summitville	13.0	83.7
	Bedford, Columbus	24.5	63.5
	Cincinnati, Cincinnati	52.5	150.5
Glacial	Lima	74.0	80.0
	Findlay	46.2	48.0
	Upper Sandusky	72.5	91.2
	New London	56.7	53.0
	Mt. Healthy	23.2	19.0
	London	51.2	48.5
	Toledo	70.0	43.0
Alluvial	Sugar Creek	41.5	49.5
	Westerville	75.0	75.2
	Beaver	79.5	83.7
	Zanesville (loess)	50.5	51.7
	Gallipolis	128.7	112.0
	Zanesville	135.7	122.5

Same amounts of water used for each clay or shale in commercial grind and ball milled.

PHYSICAL PROPERTIES OF BODIES COMPOSED OF POTTER'S FLINT AND CLAY.

THE china clay investigation in progress at the Columbus branch of the bureau includes a study of the clays in bodies as well as a study of the clays alone. The composition of one set of bodies is 50 parts potter's flint and 50 parts clay, while the other is 50 parts clay, 30 potter's flint, and 20 feldspar. It is believed that the real reasons for the differences in the clays will be brought out more clearly by studying the reactions when in bodies as well as when treated individually. The general purpose of the investigation is to compare English and American china clays, but as yet only the English have been studied. Of these, seventeen commercial brands are being used. During the past few months the work on the

bodies composed of potter's flint and clay was carried out and is nearly completed.

Each of the clays was made up with an equal weight of potter's flint into a body; the size of specimens and procedure of making and testing following closely the specifications of the American Ceramic Society. The properties evaluated on the unfired bodies were those of volume shrinkage, shrinkage water, pore water, water of plasticity, bulk specific gravity, slaking time, and modulus of rupture. On the fired bodies values for volume shrinkage, porosity, bulk specific gravity, and modulus of rupture were determined at seven different temperatures namely, cones 3, 5, 8, 11, 14, 18, and 23.

The various bodies have so nearly the same value for any one property that for the present purpose, averages only are given. To show the effect of the flint, general averages for the clays alone are also given.

Dry Properties of Clays and Bodies.

Material.	Properties.						
	Volume Shrinkage.	Shrinkage Water.	Pore Water.	Water of Plasticity.	Bulk Specific Gravity.	Slaking Time.	Modulus of Rupture.
	per cent.	per cent.	per cent.	per cent.		hours.	lbs./in.[2]
Clays alone..	18.6	11.6	29.8	41.3	1.46	7.7	88.0
Bodies......	11.6	7.1	20.4	27.5	1.64	6.6	46.6

Fired Properties of Clays Alone.

Property.	Cone.						
	3	5	8	11	14	18	23
Volume shrinkage [1]....	20.0	26.3	32.5	41.7	48.8	48.5	48.5
Porosity [1]............	40.3	35.9	29.0	17.5	3.9	1.2	1.0
Bulk specific gravity...	1.60	1.75	1.91	2.17	2.45	2.50	2.50
Modulus of rupture [2]...	—	—	2,200	3,000	4,000	5,500	6,000

[1] Values in per cent.

[2] Expressed in lbs./in.[2]

Fired Properties of Bodies.

Property.	Cone.						
	3	5	8	11	14	18	23
Volume shrinkage [1]	7.3	8.4	9.6	12.2	17.8	26.2	31.1
Porosity [1]	34.9	34.3	33.7	33.7	26.4	15.7	2.7
Bulk specific gravity	1.64	1.66	1.68	1.72	1.83	2.06	2.21
Modulus of rupture [2]	35	450	765	890	1,350	2,000	2,600

UNSLAKABLE RESIDUE IN QUICKLIME.

HYDRATED lime is produced from quicklime by treating quicklime with water in one of several different methods. The hydrate produced is usually in a very fine state of subdivision, however, to insure a uniformly fine product it is common practice to separate the fine material from the coarse by a process of air separation. Occasionally it is found that an undue amount of coarse residue is obtained. When the amount is large it represents a considerable loss to the producer of the lime, and it is consequently desirable to reduce the amount of residue to a minimum.

As it was considered of general interest and value to lime producers, the bureau has investigated the nature of unslakable residues. A sample of quicklime known to give considerable residue and a sample of the stone from which the quicklime was made were obtained. A weighed amount of the quicklime was added to a slight excess of water, stirred until slaking was complete, and then washed by decantation until the water ran clear. This process produced a residue which was dried in an oven at 110° C. and then weighed. It was found that the method gave about 5 per cent. residue in the form of hard gritty lumps, the largest of which were approximately one-eighth inch in diameter. This was ground in a mortar until it passed a No. 200 sieve. It was then analyzed by the method outlined in Bureau of Standards Circular No. 204.

Samples of the stone and of the quicklime were also analyzed by the same methods. SO_3 determinations were

[1] Values in per cent.

[2] Expressed in lbs./in.^{2}

made on all three materials by the methods given in Bureau of Standards Circular No. 33. The following results were obtained. They have been calculated to the non-volatile basis.

Determination.	Stone.	Quicklime.	Residue.
SiO_2	.97	1.00	3.08
R_2O_3	.25	.36	.79
CaO	98.20	97.80	80.90
MgO	.45	.53	15.45
SO_3	None	Trace	Trace

It is evident that the silica is somewhat concentrated in the residue. It is also evident that the greater part of the MgO from the stone has concentrated in the residue.

From the limited data it is impossible to draw any generalizations. It is hoped that future work on this subject may result in some conclusions which will be helpful in eliminating this undesirable waste in hydrated lime production

REMOVAL AND EXAMINATION OF SOIL-CORROSION SPECIMENS.

THE plans of the Bureau of Standards soil-corrosion investigation call for the removal of parts of the specimens at two-year intervals. In accordance with these plans the work of removing specimens of iron and steel pipe and lead cable sheath which have been buried for six years is well under way and will be completed during the present month. The specimens are returned to Washington where they are cleaned and the rate of corrosion and pitting determined. The specimens are then photographed and stored. About 1,000 specimens will be removed this year.

A report on the results of the 1928 examination will be available early next year.

The Bureau recently issued its first report on its soil-corrosion work as Technologic Paper No. 368, "Bureau of Standards Soil-Corrosion Studies. I. Soils, Materials and Results of Early Observations." Owing to the demand for this publication the Bureau's supply for official distribution has been exhausted, but it can be secured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 50 cents per copy.

This investigation was begun in 1922 as a supplement to the study of corrosion due to stray electric currents. It had become evident that in some cases where serious corrosion had occurred the cause of the corrosion could not be definitely determined until it was known whether such corrosion could occur in natural soils where no stray currents were present. The original investigation was therefore quite limited in its scope. The results obtained soon showed beyond question that corrosion of metal structures in soils was an extremely important problem in itself. Incidentally some other tests have shown that the processes of corrosion may include the production of rather large electric currents in pipe lines even when there are no extraneous sources of current.

A very wide interest has been manifested in soil corrosion, and many questions have been raised which can not be answered by the data which are being obtained. The work will not be finished for several years, but because of the interest manifested and the plans for corrosion studies that other organizations are considering, it has seemed advisable to set forth in some detail the plans and scope of the bureau's investigation and to publish and discuss such data as are now available as a result of the investigation. The data indicate that in certain regions soil corrosion is an active enemy of buried pipe lines, that the material best suited to resist the action of one soil is not necessarily the best for other soil conditions, and that the use of some form of a protective coating is desirable under a number of soil conditions.

Because the rates of corrosion so far observed may not continue and because the rate for one material may change more than the rate for another, no conclusions can be drawn at this time as to the ultimate life of any of the materials under test nor of the relative merits of materials that are nearly alike. So far as observations on the materials are concerned, the report given in Technologic Paper No. 368 is therefore preliminary in its nature.

EFFECT OF RELATIVE HUMIDITY AND TEMPERATURE UPON THE PHYSICAL PROPERTIES OF VULCANIZED RUBBER COMPOUNDS.

The work of the Physical Testing Committee, Rubber Division, American Chemical Society, carried on at the

bureau during the last year, in which the effect of temperature and humidity upon the stress-strain relation, both subsequent and prior to vulcanization, was investigated, will soon be published in *Industrial and Engineering Chemistry*. Several thousand tests were made covering a range of relative humidity from 0 to 100 per cent. and a range of temperature from 5 to 45° C. These ranges were covered with 5 compounds and each compound was represented by a range of 5 cures.

The work is now being extended with three of the compounds used previously, and an additional one which simulates a commercial heel compound, in a study of resistance to abrasion. This resistance to abrasion is being determined over a range of temperatures and humidities. The investigation is only partially completed, but it has been found that a difference of 20° C. may cause a 25 per cent. change in resistance to abrasion. This difference due to temperature varies both in degree and kind with the compound used.

Measurements of resistance to abrasion are being made in each case with two machines of quite different types. The Grasselli instrument, which works on the Prony brake principle, gives results in volume abraded against an emery paper, per horsepower hour, while the U. S. machine records the volume abraded per hour by a wheel bound with emery cloth, with no power measurements taken.

PERMANENCE OF BOOK PAPERS.

The Bureau of Standards has recently initiated, as a part of its general study of the permanence of paper, research on the permanence of book papers. This particular line of investigation was taken up for two reasons. One is to make certain that the paper used for the research publications of the Bureau will have the desired permanence. The other is on account of the rapidly increasing interest in general in preservation of printed matter of permanent value. An illustration of this interest is the recent development, in which the Bureau coöperated, of a newsprint paper made of rag fibers for printing special permanent issues, of newspapers for libraries. Such issues are being made by a number of publishers.

There is interest in a similar project, especially on the part of the American Library Association, for books and other bound printed matter.

The immediate work planned is the testing of products on the market at the present time. These will include complete chemical and physical tests to find the composition of the papers, accelerated aging tests made by exposure to heat and light, studies of the effect of the constituents of the papers on their permanence, and coöperative work with manufacturers to correct any properties of the papers that may be found undesirable from a permanence viewpoint.

VAPOR LOCK IN AIRPLANE FUEL SYSTEMS.

EXPERIENCE in the altitude chamber of the Bureau of Standards indicates that occasional engine failures and more frequent erratic performance of airplane engines are caused by the permanent or temporary interruption of normal fuel flow due to the formation of gas bubbles in the carburetor jet or elsewhere in the fuel system. This difficulty is known as "vapor lock" and is most likely to occur with fuels containing an excess of the more volatile constituents or of dissolved gases.

The provision in the present aviation gasoline specifications which says that the 5 per cent. point on the American Society for Testing Materials distillation curve shall not be lower than 50° C. (122° F.) was placed there as a protection against vapor lock. It is believed, however, that this particular limitation on the volatility of aviation gasoline excludes some gasolines which are not likely to cause vapor lock admits others which are liable to cause vapor lock.

A study of aviation gasolines is now in progress at the Bureau, with the object of developing means of distinguishing between fuels which are suitable for use in airplane engines and those which are unsuitable from the point of view of possible difficulty from vapor lock.

THERMAL EXPANSION OF MAGNESIUM AND SOME OF ITS ALLOYS.

AN investigation on the linear thermal expansion of pure magnesium, magnesium-aluminum alloys, and magnesium-

aluminum manganese alloys has recently been completed. Magnesium, the lightest structurally used metal, and its alloys, are becoming more prominent for materials of construction where lightness and strength are important factors, for example in aircraft manufacture and for moving parts of gasoline engines.

Expansion determinations were made on six samples of cast and extruded magnesium and 11 samples of cast and extruded magnesium alloys. The samples of magnesium were investigated over various temperature ranges between − 183 and + 500° C. and most of the alloys between room temperature and 300° C. Three types of expansion apparatus were used in this investigation. The average coefficient of expansion of pure magnesium was found to be 0.0000260 per °C. between 20 and 100° C.

The results obtained will be published by the Bureau of Standards. The publication will also include a summary of available data by previous observers on the thermal expansion of magnesium and a few magnesium alloys, and a figure which shows the relations between the chemical composition and the coefficients of expansion of the magnesium alloys.

Copies of the publication will be available in a few months.

RADIO AIDS TO AIR NAVIGATION.

RESEARCH work extending over two years has resulted in the development and practical demonstration of radio aids to flying on the civil airways. These aids comprise a radio beacon system marking out definite courses, and radio telephone service from ground to airplane. The whole system can be utilized by airplanes carrying no radio apparatus except a simple receiving set. This development, which was carried on by the Bureau of Standards for the Aeronautics Branch of the Department of Commerce, was briefly described in the Radio Service Bulletin, March 31, 1928, on page 19. A technical description of the work, "Development of Radio Aids to Air Navigation," by J. H. Dellinger and Haraden Pratt, was published in the *Proceedings of the Institute of Radio Engineers*, July, 1928, page 890.

In the same issue of the *Proceedings*, page 985, there is

given a "Bibliography on Aircraft Radio," by C. B. Joliffe and Elizabeth Zandonini. This bibliography includes 257 references to foreign and domestic periodicals.

Copies of these two reports are not available from the Government. A copy of the *Proceedings of the Institute of Radio Engineers* may be obtained from the Institute at 33 West 39th Street, New York, N. Y., for $1.

A Pitcairn Mailwing airplane was put at the disposal of the bureau by Pitcairn Aviation, Inc., for the installation of radio receiving equipment including the visual indicator. This airplane is to be used later by this company in its regular air mail service from New York to Atlanta which passes through Washington, and will make use of the College Park beacon. This will give a test of the beacon system under actual conditions of use. The high tension ignition system of this airplane was completely shielded, the leads from the magneto distributor blocks to the spark plugs were replaced by shielded high tension cable drawn through the conduit manifold rings, shielding plates put over the magneto distributor blocks, and the spark plugs covered by special caps.

Several long flights were made by this airplane in order to test the radio installation on the plane and the operation of the beacon. On one flight a range of 90 miles was obtained through severe atmospheric disturbances. In another test working reed deflections were obtained at Hadley Field, New Brunswick, N. J., using the College Park beacon.

A new Fairchild cabin airplane having a capacity of four passengers was delivered and will be used for experimental work. Ignition shielding is being installed, and the airplane will be completely equipped with radio apparatus and will constitute a flying radio laboratory.

SOME RECENT ACTIVITIES OF THE COMMERCIAL STANDARDS GROUP.

Photographic Paper.—A meeting of the simplified practice committee of manufacturers of photographic paper was held in New York on July 23, to consider the program for the simplification of photographic paper of various kinds which the committee has been developing for some time. It is

expected that the final meeting of the committee will be held this month, when the schedule of sizes will be completed, in preparation for a general conference of all interests.

Lead Pencils.—The final schedule for the simplification of lead pencils has been approved and will be placed before the industry for acceptance in the near future.

Luggage.—A member of the staff has been invited to address the Luggage Dealers Convention in New York City on August 17 on the subject "Standardizing Luggage Sizes." The National Luggage Dealers Association has worked out a suggested list of sizes for the consideration of the luggage industry, covering trunks, suit cases, hat boxes, etc. It is the opinion of some that if the industry can arrive at a standardization of sizes, it will be of great economic value to both the manufacturer and retailer.

Ice Cream Cans.—The Committee on Simplified Practice of the International Association of Ice Cream Manufacturers, in conjunction with representatives of ice cream can manufacturing companies, met June 6, 1928, in New York City, to further the program of can standardization. A display of ice cream cans now being manufactured enabled the members of the committee to compare the different types and sizes of cans and determine upon tentative standard sizes. It was recommended that these sizes be submitted at the annual convention of the International Association of Ice Cream Manufacturers at Cleveland, during the week of October 18 for consideration and criticism. When the standard sized cans are finally adopted by manufacturers, distributors, and users, it will eliminate the confusion now existing because of the many types and sizes of cans on the market, and will result in a lower production cost.

Glass Containers for Drug and Pharmaceutical Industry.—At a preliminary conference of representatives of the drug and pharmaceutical industry and the Glass Container Association held July 6, a motion was presented and unanimously carried that a joint standardization and simplification committee be appointed to consist of one voting delegate and two associate delegates from each of the National Drug and Pharmaceutical Associations and the Glass Container Association of America in coöperation with the United States Department of Com-

merce, for coördinating the efforts of the various groups concerned in the simplification and standardization of glass containers used in the drug and pharmaceutical industries.

It was also the sense of the meeting that the appointment of the committee be completed as soon as possible with the view of holding its first meeting during the week of August 6 for the purpose of organization and that this first meeting be held at the Department of Commerce under the auspices of the division of simplified practice.

In accordance with the action taken at the conference on July 6 the Bureau invited seventeen different drug and pharmaceutical associations and the Glass Container Association to send three delegates to a conference at the Department of Commerce on August 10, to complete organization of a central simplified practice committee and to discuss the question of variety surveys.

Glass Containers for Jelly and Preserves.—A general conference to discuss the simplification of jelly glass and preserve jar sizes and capacities has been postponed until some time in September. This conference will be held in Washington in conjunction with the mid-year convention of the National Preservers Association.

Type Faces.—For several months the United Typothetæ of America and the division of simplified practice have been coöperating in an effort to ascertain the views of leading printers and manufacturers of type as to the advisability of inaugurating a simplification program to reduce the excessive variety of type faces. While there are conflicting opinions regarding the matter, a large majority are nevertheless in favor of a conference to discuss the subject and to formulate some plans whereby the elimination of undesirable type faces might be brought about. At the request of the United Typothetæ of America, the division of simplified practice will arrange for a preliminary conference in the fall to consider the subject of simplification of type faces. In the meantime the division will be glad to receive any comments or suggestions which the readers of this bulletin may care to express on this subject.

Hospital Plumbing Fixtures.—A tentative simplified practice recommendation for hospital plumbing fixtures has been

worked out by the manufacturers of vitreous china, porcelain, and enameled fixtures. This recommendation is now in the hands of the standardization committee of the American Hospital Association for review and further recommendation as to definite types and sizes to be used as standard items for various purposes. After the hospital authorities have compiled their criticisms and comments, there will be joint meeting of the hospital plumbing fixture manufacturers and members of the standardization and simplification committee of the Hospital Association to develop a final recommendation covering types, sizes, dimensions, etc.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

MOTION PHOTOMICROGRAPHS OF THE PROGRESS OF DEVELOPMENT OF A PHOTOGRAPHIC IMAGE.[1]

By C. Tuttle and A. P. H. Trivelli.

IN the photomicrography of silver bromide grains during photographic development, high magnification and higher resolution are necessary to make the changes visible. In this work an oil immersion lens was used. The material to be photographed was coated on the under side of a microscope cover glass and the dilute developer was placed on the substage condenser. A convenient method of focusing and viewing the image is described. Two illustrations taken from the motion picture record of development are included.

THE REPRODUCTION OF MOBILITY OF FORM AND COLOR BY THE MOTION PICTURE KALEIDOSCOPE.[2]

By L. A. Jones and C. Tuttle.

BY combining a kaleidoscopic prism with a suitable motion picture camera it is possible to make motion pictures in color which show the changing patterns produced when a suitable grouping of colored elements is moved slowly past the end of the prism. Such color film may be used in the theater for the embellishment of the motion picture program. A description is given of an instrument constructed for making such film by the two-color process. This consists essentially of a standard Bell & Howell camera to which is added a suitable holder for the two-color taking filters, a kaleidoscopic prism, a pattern

* Communicated by the Director.

[1] Communication No. 341 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* 33: 157. 1928.

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plate of colored gelatin designs on glass, a lamp for illuminating the pattern plate, and the mechanical means for driving the various elements in synchronism. Diagrams are shown illustrating the various types of symmetrical, quasi-symmetrical, and unsymmetrical patterns formed by the use of various types of prisms. The paper is illustrated by a reel of film showing both the form and the color sequences obtainable.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY AND SOILS.*

BIOLOGICAL VALUES OF CERTAIN TYPES OF SEA FOODS.[1]

III. VITAMINS IN CLAMS.

By D. Breese Jones, E. M. Nelson, and J. C. Murphy, with the coöperation of J. P. Devine.

[ABSTRACT.]

In feeding experiments with albino rats two species of clams were used, *Venus mercenaria*, commonly known as "hard-shell clams" or "quahaugs" and *Mya arenaria*, commonly called "soft-shell clams." Both species contain little, if any, vitamin B. Soft-shell clams were found to be a somewhat better source of vitamin A. No difference was observed with respect to vitamin D.

Five grams daily of soft-shell clams, equivalent to 1 gram of dry material, was sufficient for the cure and prevention of xerophthalmia. A little more of the hard-shell clams was required. Five grams of either species given daily to rachitic rats induced complete calcification in the small bones in 15 days. The rate of calcification was not appreciably influenced by the ash constituents of the clam.

Compared with oysters, which are rich in vitamin B, clams are practically devoid of this vitamin. As a source of vitamin A clams are somewhat inferior to oysters, but they have more vitamin D, and are a better source of the factor, or factors, essential for reproduction and rearing of young.

STUDIES ON GOSSYPOL.[2]

IV. APOGOSSYPOL.

By E. P. Clark.

[ABSTRACT.]

WHEN treated with 40 per cent. sodium hydroxide at the temperature of the steam bath for half an hour gossypol is

* Communicated by the Chief of the Bureau.

[1] Published in *Ind. and Eng. Chem.*, 20: 648, June, 1928.

[2] Published in *J. of Biological Chemistry*, 78: 159–166, June, 1928.

plate of colored gelatin designs on glass, a lamp for illuminating the pattern plate, and the mechanical means for driving the various elements in synchronism. Diagrams are shown illustrating the various types of symmetrical, quasi-symmetrical, and unsymmetrical patterns formed by the use of various types of prisms. The paper is illustrated by a reel of film showing both the form and the color sequences obtainable.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY AND SOILS.*

BIOLOGICAL VALUES OF CERTAIN TYPES OF SEA FOODS.[1]

III. VITAMINS IN CLAMS.

By D. Breese Jones, E. M. Nelson, and J. C. Murphy, with the coöperation of J. P. Devine.

[ABSTRACT.]

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converted into formic acid and apogossypol, a new phenolic substance, in the proportion of 2 mols of formic acid to 1 mol of apogossypol.

Apogossypol, which has the molecular formula $C_{28}H_{30}O_6$, is formed by the elimination of the two carbonyl groups of gossypol as formic acid. All the 6 oxygen atoms of apogossypol are present as hydroxyl groups. The phenol accordingly forms a hexaacetyl derivative and a hexamethyl ether by the replacement of the hydroxyl hydrogens by acetyl and methyl radicals. In the hexaacetate, as in hexaacetyl gossypol, two of the acetyl groups are more resistant to hydrolytic agents than the remaining four. The direct determination of the methoxy groups in the hexamethyl ether could not be made as the material was entirely inert in boiling hydriodic acid as used in the Zeisel method.

The toxicity of apogossypol was determined and compared with that of gossypol. Of the two, apogossypol was considerably less toxic. The lethal dose, given intraperitoneally to white rats, was found to be from 60 to 75 mg. per kilo of body weight. The physiological action of apogossypol is in sharp contrast with that of gossypol as no chronic toxic effects follow the administration of small doses.

RESINS FROM CHLORINATED CYMENE.[3]

By P. H. Groggins.

[ABSTRACT.]

CHLORINATED resin of a new type was prepared from p-cymene by chlorination in the presence of a metal catalyst. Varieties of the resin can be obtained by previously incorporating other soluble and miscible materials with p-cymene. The resins are insoluble in acids, alkali, and alcohol, and they can not be brought to the infusible state by heat and pressure treatment. The intermediate compounds have toxic properties and are lethal to small animals and to vegetable organisms.

[3] Published in *Ind. and Eng. Chem.*, **20**: 597, June, 1928.

INSECTICIDAL ACTION OF SOME ESTERS OF HALOGENATED FATTY ACIDS IN THE VAPOR PHASE.[4]

By R. C. Roark and R. T. Cotton.

[ABSTRACT.]

THE action of the esters of some of the halogenated fatty acids in the vapor phase upon insects was tested. From the standpoints of toxicity to insects, availability, cost, and freedom from fire hazard, methyl, isopropyl, and ethyl monochloroacetates appear to be the most promising of the lower alkyl esters of chloroformic (chlorocarbonic), monochloro-, dichloro-, and trichloroacetic, monobromoacetic, alpha-bromo- and beta-bromopropionic and beta-chloropropionic acids tested. Dosages of 1 pound of methyl monochloroacetate, 1.5 pounds of isopropyl monochloroacetate, and 2 pounds of ethyl monochloroacetate per 1,000 cubic feet were effective against stored-product insects in fumigation vaults of the commercial type. As further tests, however, showed that the monochloroacetates injure the germination of wheat, these fumigants do not look promising for the fumigation of grain intended for seed.

AN OBSERVED CASE OF "SPONTANEOUS" IGNITION IN STABLE MANURE.[5]

By L. H. James, G. L. Bidwell, and R. S. McKinney.

[ABSTRACT.]

OBSERVATIONS were made upon a large pile of heating stable manure and straw at the Arlington Experiment Farm, Rosslyn, Va. Within a period of three days several different parts of the stack ignited spontaneously. Readings showed that in the center of the pile and up to within 5 or 6 feet of the outer surface the temperatures were not extremely high, 66° being the maximum, whereas within 6 inches of the surface the temperatures were much higher, averaging 80° C. In the loosely packed manure on the top, the maximum temperature was from $1\frac{1}{2}$ to 2 feet from the surface. When exposed

[4] Published in *Ind. and Eng. Chem.*, 20: 512–514, May, 1928.
[5] Published in *J. Agr. Res.*, 36: 481–485, March, 1928.

to the air, charred straw glowed a fiery red. Oxygen aëration of a small section of the heating material produced a rapid increase in temperature of 26.5° C. in 30 minutes.

STUDIES ON GLUTELINS.

IV. THE GLUTELINS OF CORN (ZEA MAYS).[6]

By D. Breese Jones and Frank A. Csonka.

[ABSTRACT.]

CORN (*Zea Mays*) contains two glutelins (α- and β-) which are precipitable from alkaline solution by the addition of ammonium sulphate to 3 per cent. and 16 per cent. of saturation, respectively.

Analyses of the α-glutelin by the Van Slyke method showed the following composition: Amide N, 7.73 per cent.; cystine N, 2.04 per cent.; arginine N, 15.11 per cent.; histidine N, 2.81 per cent.; lysine N, 7.99 per cent.; amino N in filtrate from bases, 59.64 per cent.

The isoelectric point of the α-glutelin was found to be at pH 6.45.

SPECTROPHOTOMETRIC DETERMINATION OF HYDROGEN ION CONCENTRATIONS AND OF THE APPARENT DISSOCIATION CONSTANTS OF INDICATORS.

V. FAST GREEN F C F.[7]

By W. C. Holmes and E. F. Snyder.

[ABSTRACT.]

SPECTROPHOTOMETRIC data are supplied for the determination of hydrogen ion concentrations over the pH range between 6.7 and 10.0 with Fast Green F C F. The apparent dissociation constant of the dye in this range is approximately 8.1 (5) at 29°. Within the range of pronounced acidity the dye proves a less sensitive indicator than do the sulphonephthaleins.

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[6] Published in *J. Biological Chem.*, 78: 289–292, July, 1928.

[7] Published in *J. Amer. Chem. Soc.*, 50: 1907–1910, July, 1928.

THE FLAVOR OF MAPLE SIRUP.[8]

By E. K. Nelson.

[ABSTRACT.]

INVESTIGATION of the flavor of maple sirup showed that it depends to a great extent on an unstable phenolic substance which is associated with a crystalline aldehyde melting at 74–76° and similar in odor and properties to vanillin. Maple sirup may contain minute quantities of other aldehyde substances which influence the flavor.

THE ACIDS OF MAPLE SUGAR "SAND."[9]

By E. K. Nelson.

[ABSTRACT.]

THE acids of maple sugar "sand" were separated and identified. In addition to l-malic acid, formic, acetic, fumaric, succinic, and citric acids were found. There was evidence of traces of α-tartaric and tricarballylic acids. A small quantity of an unknown acid represented by a hydrazide melting at 173–175° was found.

THE ACIDS OF MAPLE SIRUP.[10]

By E. K. Nelson.

[ABSTRACT.]

MAPLE sirups from Vermont and from Michigan were analyzed to determine the acids. In addition to malic acid, which predominates, formic, acetic, and citric acids were identified. Also, a small quantity of fumaric acid and a trace of succinic acid were found. There was evidence of the presence of a small quantity of an unidentified acid having a high melting point. Neither α-tartaric acid nor tricarballylic acid could be found.

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[8] Published in *J. Amer. Chem. Soc.*, 50: 2009–2012, July, 1928.
[9] Published in *J. Amer. Chem. Soc.*, 50: 2028–2031, July, 1928.
[10] Published in *J. Amer. Chem. Soc.*, 50: 2006–2008, July, 1928.

THE ACIDS OF FIGS.[11]

By E. K. Nelson.

[ABSTRACT.]

ACETIC and citric acids were found in Adriatic figs; acetic, citric, and a small quantity of malic acids were identified in Calimyrna figs. The Adriatic black neck figs contained more than 10 times as much acetic acid as did the normal Adriatic figs, and less citric acid was found in them than in the normal figs. Normal Calimyrna figs contained 0.26 g. per kilo of free acetic acid and 3.5 g. of citric acid, besides a small quantity of malic acid. In Calimyrna figs affected with internal rot the free acetic acid amounted to 0.56 g. per kilo, and the citric acid amounted to 3.3 g. per kilo.

THE VALUE OF INERT GAS AS A PREVENTIVE OF DUST EXPLOSIONS IN GRINDING EQUIPMENT.[12]

By Hylton R. Brown.

[ABSTRACT.]

THE records for a 20-year period show that in feed grinding plants alone the 30 principal explosions caused the loss of 60 lives, injury to 118 persons, and property damage amounting to approximately $5,000,000. Eighteen of these explosions originated in the grinding equipment where it was impossible to prevent the formation of dust clouds or to eliminate sources of ignition. Experiments conducted by the Bureau of Chemistry and Soils have shown that it is practicable to use inert gas for flooding the inclosures of the grinding equipment and diluting the oxygen content to such a point that fires or explosions can not take place. The results of this investigation are described in United States Department of Agriculture Technical Bulletin 74.

This bulletin describes the experimental plant, the equipment used, and the tests conducted to determine the value of inert gas in preventing explosions. It discusses the effect of

[11] Published in *J. Amer. Chem. Soc.*, 50: 2012–2013, July, 1928.

[12] United States Department of Agriculture Technical Bulletin 74. Issued June, 1928.

the gas on employees, and on the material ground, the quantity of flue gas required, and the equipment necessary. It gives directions for designing and installing an inert gas system, both where the flue gas is available and where it must be obtained from gas-producing apparatus, including a discussion of the normal air requirements, the necessary reduction of oxygen, the oxygen percentage of gas, the quantity of gas required, the quantity of gas available, and the gas-conditioning and the gas distributing equipment.

THE COMMERCIAL PRODUCTION OF SAUERKRAUT.[13]

By Edwin LeFevre.

[ABSTRACT.]

UNITED STATES Department of Agriculture Circular 35 describes the commercial production of sauerkraut. Sauerkraut is shredded cabbage which has undergone a lactic fermentation in a brine made from its own juice by the addition of salt. It should be made from the slow-growing, solid-headed varieties of cabbage, which should be fully mature before harvesting. The cabbage should be cut in shreds about as thick as a dime, and salted with about 2½ pounds of salt for each hundred pounds of cabbage. The finished product should be crisp and as free from color as possible, and should have an acidity of not less than 1.5 per cent. and preferably nearer to a maximum of about 2 per cent., calculated as lactic. Pure cultures of the fermenting organisms may be of some benefit in sauerkraut manufacture, but have not yet proved practical in commercial production or an improvement that warrants the time and expense required for their introduction. The most favorable temperature for the start of the fermentation is about 86° F. In places where the temperature is much colder than this when the cabbage is harvested and sliced, steam heating the cabbage is advisable to promote rapid fermentation to a maximum acidity.

This circular contains suggestions for the construction of a

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[13] United States Department of Agriculture Circular 35. Issued June, 1928.

factory, considers the bacteriology of sauerkraut production, discusses the factors that influence quality, describes the processes of manufacture and the methods of marketing, the sanitary measures required, the desirability and methods of canning as compared to marketing in bulk, and includes an abstract of the Federal regulations governing the manufacture and sale of sauerkraut.

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LIBRARY NOTES.

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BOOK REVIEWS.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 285. A Study of Wing Flutter, in three parts, by A. F. Zahm and R. M. Bear. 28 pages, illustrations, quarto. Washington, Government Printing Office, 1928, price 15 cents.

Part I describes vibration tests, in a wind tunnel, of simple airfoils and of the tail plane of an MO-1 airplane model; it also describes the air flow about this model. From these tests are drawn inferences as to the cause and cure of aerodynamic wing vibrations. Part II derives stability criteria for wing vibrations in pitch and roll, and gives design rules to obviate instability. Part III shows how to design spars to flex equally under a given wing loading and thereby economically minimize the twisting in pitch that permits cumulative flutter.

Resonant flutter is not likely to ensue from turbulence of air flow alone past wings and tail planes in usual flying conditions. To be flutterproof a wing must be void of reversible autorotation and not have its centroid far aft of its pitching axis, i.e., axis of pitching motion. Danger of flutter is minimized by so proportioning the wing's torsional resisting moment to the air pitching moment at high-speed angles that the torsional flexure is always small.

Report No. 288. Pressure Distribution Over a Rectangular Monoplane Wing Model Up to 90° Angle of Attack, by Montgomery Knight and Oscar Loeser, Jr. 19 pages, illustrations, quarto, price ten cents.

The pressure distribution tests herein described, covering angles of attack up to 90°, were made on a rectangular monoplane wing model in the atmospheric wind tunnel of the Langley Memorial Aeronautical Laboratory.

These tests indicate that a rectangular wing, by reason of its large tip loads, is uneconomical aerodynamically and structurally, has pronounced lateral instability above maximum lift, and is not adaptable to accurate calculation based on the classical wing theory.

ICE ENGINEERING. By Howard T. Barnes, F.R.S. 364 pages, illustrations, 8vo. Montreal, Renouf Publishing Company, 1928. Price, $5.

In all hydraulic projects located in climates where freezing temperatures occur, the careful consideration of ice formation is of paramount importance. Some twenty odd years ago, the author analyzed the phenomena of ice-formations in their various phases in his rarely interesting treatise "Ice Formation" (Wiley & Sons, N. Y., 1906). Therein he described some of the serious obstacles to the operation of hydraulic power plants incident to such accumulations of ice as well as their frequently destructive effects upon nearly all types of hydraulic works. The author's investigations in recent years have added materially to our knowledge of rational methods, of meeting these baleful effects of ice formation in the operation of hydraulic power projects and these advances he chronicles in his new book which deals specifically with the engineering aspects of the ice problem.

Almost one-half of the book deals with the physics of ice-formation which is considered in its most modern aspects as, for example an account of the colloidal character of the ice particles which flocculate and finally form a true ice crystal. Again there is an analytical discussion on the rate of growth of ice with reference to the work of Dr. S. Tetsu Tamura and that of Prof. L. V. King of McGill University and others. The important forms known as anchor ice and frazil ice are given a lengthy consideration at the end of this part of the subject.

The applications of remedial measures against prejudicial ice formation occupy another division of the work. Among these are considered, steam, thermit and other chemicals. The author's investigations in the use of thermit and its application in the removal of ice jams are a classic which has received wide publicity in technical and popular science journals. Another important branch, ice navigation and ice breaking, receives an equally thorough survey. Among other topics of practical value are, conservation of heat in lakes and rivers for ice prevention, glaciers and icebergs and another application of thermit for the destruction of icebergs. A copious classified bibliography is included at the end of the work.

The work contains a very large amount of statistical and, where possible, of analytical information of great value to the hydraulician operating in cold climates as well as of deep interest to the serious general reader.

LUCIEN E. PICOLET.

THE FALLS OF NIAGARA. By Glenn G. Forrester. 155 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928. Price, $2.50.

The United States is favored by having within its borders an unusually large number of great natural scenes. Niagara, the Yellowstone, the Yosemite, the petrified forest, and the Grand Canyon, the last considered by many the most impressive sight in the world. Of course, in such a vast area as our country covers, one would expect much variety in scenery, but the geologic history of North America has been especially fertile in producing high contrasts and profound modifications.

The volume in hand is an instructive account of the present state of the great cataract, of its development and the principal incidents in its career as far as the testimony of the rocks can show. There is appended a guide to the falls and its environment. The history of the cataract involves the story of the glacier period and evidences of its actions. Decidedly different geographical conditions in earlier periods have been found by geologists which are set forth in careful description and by numerous maps. Many excellent plates are also included. The book is entertainingly written. The future of the cataract is a matter of interest. There is no doubt that it has worked its way back for a great distance, by corrosion of the rocks, and that it is still steadily retreating, but this movement will not interfere with the attractiveness of the scene for many centuries. A serious danger, however, threatens from the economic side. The water-power that it represents has already resulted in the diversion of one third of the supply and in time the diversion may be such that the Falls will be on exhibition only on Sundays and holidays. An admirer of nature will be inclined to say with Hector:

"May I be dead before that dreadful day
Presses with a load of monumental clay."

HENRY LEFFMANN.

THE PHYSICS OF CRYSTALS. By Abram F. Joffé, Ph.D., D.Sc., D.Eng., LL.D., Director, Roentgen Institute; Director, Physical Technical Institute. Edited by Leonard B. Loeb, Associate Professor of Physics in the University of California. xi–198 pages, 61 figures, 8vo, cloth. First Edition, New York, McGraw-Hill Book Company, Inc. Price, $3.

Gilbert N. Lewis, in his introduction to this volume, speaks thus: "In late years the great rush to the new gold fields of physics has caused a temporary abandonment of tne well worked but still rich leads of classical physics. The author has returned to one of the most old-fashioned of physical themes in his study of the mechanical and electrical properties of solids, and in this rejuvenation of an ancient problem with the aid of all modern resources of theory and practice, our admiration is divided between the ingenuity of the methods devised and the technical skill shown in their application."

As the author states in the preface, this book represents the organization into a consistent system of the results of a number of investigations on the physics of crystals which the author and his collaborators have been carrying on for the last twenty-five years. The subject matter covers a limited portion of the field of elastic and electrical properties of solids, particularly crystals.

The first six lectures deal with the mechanical properties and behavior of crystals while the remaining eleven are concerned with the electrical behavior of both single crystals and solid dielectrics. The introductory lecture outlines the electrical theory of crystal lattices with a view to effecting the visualization of a mechanical model. This is followed by both a general and a mathematical discussion of equilibrium in a crystal lattice. A systematic series of experiments upon the elastic after-effect have shown that all such disturbing phenomena are a result of irregularities existing in the crystal. X-rays have been used in the study of the elastic limit of crystals and the mechanism of their plastic deformation. A carefully conducted series of experiments has accounted for the anomaly existing between the calculated strengths of crystals and those observed under the application of mechanical stress.

The lecture upon the conduction of electricity through crystals demonstrates once more the validity of Ohm's law for the flow of electric current. A close study of the specific conductivity of crystals emphasized further the necessity of working with a pure material. Careful experiments on the electrolysis of crystals show that for a certain quantity of electric energy passed there is transported a corresponding number of ions possessing a total charge equal to the amount of electricity passed. Special studies have been made on the electrical behavior of both quartz and calcite. Among other subjects the author has made a study of electronic conductivity in crystals. Such a conductivity is influenced by the application of wave energy from some external source. Calculations on the amount of energy necessary to displace an electron from its atom and the crystal lattice also have been made. The problem of dielectric losses and the breakdown of dielectrics by heat and by ionization are treated mathematically and many examples of seeming anomalous behavior are explained Much interesting information has been gained through the study of the dielectric strength of thin strips of material. There is every indication that breakdown is caused by the enormous mechanical pressure exerted by the two electrodes due to their induced attraction for each other. Important technical applications of these strong electric fields which now may be obtained without breakdown of dielectrics are cited by the author. Some of these are: (1) construction of condensers of a very high capacity and a high breakdown potential; (2) the use of such condensers as storage batteries giving a high degree of concentration of energy; (3) these attractive forces could be used to replace electromagnets and relays; (4) the ionization by collision by such fields might be used as an effective amplifying device.

Dr. Joffé is to be congratulated upon the manner in which he has arranged and presented the facts with their corresponding theoretical considerations. Moreover, great credit is due to Prof. Leonard B. Loeb for his able work in editing all this material. Such a book should be of value to the physicist, chemist, and metallurgist in particular. T. K. CLEVELAND.

MECHANOCHEMISTRY AND THE COLLOID MILL. By Pierce M. Travis, President, Travis Colloid Research Co., Inc. 191 pages, 17 illustrations, cloth, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $4.

Such a book as this may be considered interesting even from the chronological standpoint. It is truly representative of the progress made in the last

two decades in the organization of a vast quantity of empirical knowledge arising from a study of colloids. This type of treatise might be viewed as a step in advance of the colloid laboratory manual for it deals with the application of general, colloid-chemistry principles to the practical arts.

"Mechanochemistry" is the name given by the author to the process of mechanical dispersion involving the principles of physical chemistry. The subject matter includes, first, a practical discussion of the relationships existing between matter in various states, i.e., degrees of dispersion and its corresponding physical and physico-chemical properties; second, the application of such knowledge toward the successful dispersion of materials and third, the various types of mechanical apparatus used to accomplish such dispersion. Some idea as to the applications of these colloid mills may be obtained when it is found that they are used for the emulsification of vegetable, animal and mineral oils, resins and waxes, the manufacture of paints and enamels, improvement of milk in regard to digestibility and the making of ice cream, extraction of oils, fats, resins and juices from vegetable or animal tissues, purification of organic chemicals, liquids and solids, intimate mixing of foodstuffs as in the preparation of sauces and salad dressings, dispersion of solids such as mica, certain oxides, fine clays, various dyes and other such materials.

The aurhor has appropriately incorporated a chapter on the elementary structure of matter which will aid greatly toward the visualizing of particles in the colloidal state. Proper stress has been laid upon the part played by electrical charges and hydrogen ion concentration. One of the more important chapters deals with the protective action of colloids in dispersions which is exemplified still further by chapters on the dispersion of solids and liquids in gas, of solids in liquids and the theory of emulsions and emulsification, i.e., the dispersion of liquids in liquids. The construction and operation of various colloid mills are clearly described and their respective utilities critically considered. The book is concluded by a brief chapter on laboratory methods and physical testing of properties.

On the whole, the book is very well written and what might seem to be redundancy in various cases is merely reiteration employed by the author for the purpose of emphasis. There seems to be an incorrect and contradictory statement made at the top of page 70. In referring to the concentrations of potassium, barium and aluminum ions required to agglomerate particles of arsenic trisulfide to the same degree the ratio is given as 1 : 20 : 1000 whereas it should be reversed. It is probable that Fig. 16 would appear more natural if inverted.

There is no doubt but what "Mechanochemistry and the Colloid Mill" will be of great value to the chemical engineer. Moreover, it should prove its worth as a reference work in the libraries of consulting chemists and engineers and something which would pay every student of chemical engineering to read.

T. K. CLEVELAND.

Matter, Electricity, Energy. By Walter Gerlach, o. ö. Professor, University of Tübingen. Translated from the second German edition by Francis J. Fuchs, Ph.D., St. John's College, Brooklyn, N. Y. xii–427 pages, 119 figures, cloth, 8vo. New York, D. Van Nostrand Company, Inc., 1928. Price, $6.

To the biologist, geologist, physicist, chemist, engineer, technologist and others whose work or interest involves an intimate relationship with some branch of scientific knowledge there occasionally arises a desire for a closer acquaintance with the fundamental concepts and basic theories seeking to explain the why and the wherefore of various natural phenomena. Those, whose occupational pursuits have not necessitated a knowledge of physics deeper than that furnished by the prescribed general courses in college are vaguely aware that many new and significant facts concerning matter and energy have been discovered and as a result of these findings the older theories have been discarded or altered to a radical extent. This book is recommended to those who wish to acquaint themselves to a greater or less degree with the more recent discoveries, the lines of research pursued and the trend of contemporary thought in the realm of physics. This book has been written for those who possess at least a general knowledge of physics and the concepts implied by the simpler terms. It was not compiled with the intention of popularizing the subject in the mind of the layman.

The author does not attempt to treat exhaustively each subject but only to furnish a general, yet very comprehensive survey of the whole field. The first edition appeared in Germany in 1923 and met with an extremely friendly reception. In many cases professors adopted the book for the graduate students in seminar work. In the second edition (1926) the author has attempted to fill in some of the gaps and make its scope that much broader. The title would lead the reader to expect a discourse on anything and everything under the sun. However, a glance through the table of contents will indicate that the book deals with the atom, its structure and the relations between that structure and the accompanying energy phenomena.

Chapter one on General Atomistics serves as a fitting introduction to that which follows. Attention is directed toward the changing definition of an element which has had to be revised due to the discovery of the radioactive transformation of matter. Elements no longer are held to be indestructible. Examples are given showing the limitations of chemical methods in bringing about the discovery of new elements and its replacement by the method of X-ray spectral analysis. The chapter is concluded by some observations upon the uncertainty of the mechanical explanation of atomic and inter-atomic processes and the many perplexing problems involved in the use and interpretation of the quantum theory. The subject of isotopy is discussed very thoroughly particular attention being paid to latest improved methods of isotope determination and their subsequent separation. In addition the chapter contains a theoretical discussion on the relation between the line and band spectra of an element and its isotopes.

Like a weed the existence of atomic rays in the wrong place has proven a nuisance. These latter are responsible for the blackening of the interior walls of incandescent light bulbs. However, in chapter three, the author relates how the physicists have utilized atomic rays in the determination of molecular thermal

velocities, the mean free paths of molecules and the experimental confirmation of the magnetic moment of individual atoms.

The study of molecular dipoles leads into a field of vast experimental possibilities. What results have been obtained in preliminary research seem to indicate that such physical properties as dielectric constant, dispersion of electric waves, viscosity, electric double refraction are inextricably linked with the existence of molecular dipoles.

Probably no phenomenon has furnished so much information concerning the ultimate structure of molecular nuclei than that of their disruption by alpha particles. A close study of these effects has led to the concept of the nuclei being constructed from "bricks" which represent hydrogen and helium atoms.

Probably chapters six and seven contain material possessing greatest fundamental interest, i.e., the fundamental unit of electricity and the relation between this unit and the mass of that particle of matter bearing it. It is noteworthy that in this phase of physics more than in any other has such a wealth of experimental evidence been available for application to the numerous controversies. A discussion of the "magneton" logically follows the two foregoing chapters. The assumption is made that each atom becomes an individual magnet by virtue of charged electrons rotating around it. It is noteworthy that a theoretical treatment of the subject indicates the magnetic moment of the atom to be dependent upon only the specific charge and Planck's constant.

An extremely interesting phenomenon is that of superconductivity as evidenced by some metals at very low temperatures. A plausible explanation of this anomalous behavior is still lacking. Up to the present, studies upon crystal conduction have disclosed many remarkable facts. A comparison between the ionic conductivity of crystals and the electronic conductivity of metals emphasizes their respective behavior towards incident light, the former being transparent while the latter reflects.

The next two hundred pages—equal to half the book—are concerned with what is probably the most important phase of physical science, namely, spectra and spectra analysis. Naturally the subject is introduced by a discussion of the quantum theory and an explanation in general terms of the mechanism of radiation by the atoms. Hydrogen, possessing the least complicated structure of all the elements, has been studied intensively in respect to its spectrum. The agreement between the observed wave-lengths of the spectrum lines and the lengths calculated by a simple formula is truly amazing. The author has set forth clearly the experimental evidence indicating that the Roentgen rays (X-rays) possess the nature of electro-magnetic pulsations. The problem of measuring the intensity of X-ray spectra has proved similar to one involved in finding a container for an universal solvent. X-rays, coming in contact with the measuring apparatus often excited a second series which would lead to erroneous results. A brief outline of the correlations existing between the spectral emissions of an atom and its position in the periodic system serves to emphasize further the belief that we are on the right track in our postulations regarding atomic structure.

An idea how the Bohr theory could serve to stimulate experimental investigation on emission and absorption phenomena taking place within an atom will be gained in a perusal of chapter sixteen. The chapter following deals with specific cases of resonance and dispersion as effected by X-radiation, and includes

a discussion of the Compton Effect in that connection. It is interesting to learn that practically all the gaps long existent in the electro-magnetic spectrum have been filled in, at last. The first portion recognized, that of visible rays, soon was extended in either direction; to the infra-red in the region of longer wave-lengths and the ultra-violet in the shorter. The discovery of the Hertzian waves (radio waves) and the Roentgen rays (X-rays) occurred at about the same time. As a result two gaps existed, one between the infra-red and the longer radio waves and the other between the ultra-violet and the shorter X-rays. Discovery of the gamma ray shorter still than the X-ray extended the spectrum still further into the region of shorter wave-lengths. Since this book was written discoveries by Millikan indicate the presence of an extremely short and highly penetrative ray (cosmic ray). The gap in the longer wave-lengths has been narrowed by an approach from both directions, namely, the production of very short radio waves and extra long infra-red or heat waves. The gap in the shorter wave-lengths has been eliminated chiefly by investigations of the longer X-rays. It will be conceded that a more extended study of the rays in these hitherto little known regions will throw considerable light upon the state and structure of matter since it is generally recognized that the waves below the ultra-violet region are produced by electrons; those in the ultra-violet and visible by similar but less energized particles while those in the infra-red and beyond by atoms, molecules and aggregates of molecules.

The photo-electric effect which is the ability of certain substances to emit negatively charged electrons when illuminated is discussed in regard to theory and, its application by means of the photo-electric cell to the examination of photographs of band and line spectra. Many readers will be more aware of its application in the realm of television and telephotography. A short chapter on spectrophotometric problems points out the troubles encountered in the measurement of the energy distribution in the spectrum produced by a hot body. Sufficient work has been done upon the reflection of infra-red rays from crystals to show that the selective reflection exhibited may be attributed to the presence of certain molecular groups or radicals composing the crystal. On the other hand application of X-rays also has been made for the elucidation of crystal structure. By means of X-rays it is possible to depict just how the crystal is constructed by indicating the relative positions of the atoms.

With the introduction of the quantum theory into photochemistry A. Einstein has taken a long step toward placing photochemical reactions upon a quantitative basis particularly by showing that to produce a definite chemical change a definite amount of energy always must be absorbed. In a discussion of luminescence in chemical reactions the author points out that certain visible radiations are emitted by the atom without concurrent thermal excitation. Attempts have been made to account for this phenomenon theoretically by means of the quantum theory. A further application of the quantum theory is to be found in the calculation of electron-affinities; i.e., the energy involved when an electron is separated from an atom during ionization. The chapter on chemical reactions by means of electronic impact is relatively short and contains none of the later work along this line carried out by such persons as S. C. Lind, W. D. Coolidge and others.

In the chapter on photochemical catalysis the sensitization of photographic

plates is discussed and a possible mechanism for the action of the sensitizing substance submitted. Under "Radiation Measurements" the author summarizes the work which has been done on the determination of Stefan-Boltzmann and Planck constants through the medium of black-body radiation. Mention is also made of the very delicate experiments performed to establish the existence of radiation pressure. There is no doubt but the final chapter on "Atomism and Macrocosmos" possesses great general interest. In it is summarized as a review that available physical knowledge which might prove helpful in astral-analysis. This is followed by a list of the essential facts of astronomy and of experimental astro-physics. The chapter ends with a most interesting exposition on the application of present physical knowledge in the elucidation of star characteristics, such as temperature, size, distance and elementary composition.

Naturally in such a work as this typographical errors are bound to creep in and are not worth the mention. However, in one or two instances, there has appeared an error or omission to which attention might be called. On page 128, Fig. 28, the positions of the two photographs of atomic rays should be reversed in order to agree with the subtitle. In the third column of the table on page 168 the figures are correct but the decimal point seems to be misplaced, judging from the column heading. In Fig. 80, page 329, the designation of the abscissas of the curve has been omitted, while on page 372 there was a failure to state whether the temperature of a blast flame is ° C. or ° F. In speaking of the reduction of oleic acid the statement is made that it was "hydrated whereas "hydrogenated" is the correct word. The word "undubitably" could well be changed to "indubitably" and the retention of the German word "zeolith" seems unnecessary since we have the corresponding English word "zeolite."

Anyone who has attempted to translate a scientific treatise from one language to another realizes that to be successful, the translator also must be well acquainted with the subject involved. It is evident that Dr. Fuchs possesses all the necessary attributes for one cannot help being impressed by the almost unfailing use of the correct shades of meaning. The translator as well as the author is to be congratulated for this English edition, the production of which is an art within itself.

T. K. CLEVELAND

ORGANIC CHEMISTRY. A brief introductory course. By James Boyant Conant. 291 pages, illustrations, 8vo. New York, The Macmillan Company, 1928.

This book differs notably from the ordinary elementary manuals of organic chemistry. It treats the subject in what may be called a topical manner. The text proper begins with a description of the alcohols, taking the common one as being of so much practical importance as to be suitable for an introductory study. The method of finding its molecular weight is presented (that is, arithmetically) and the formula deduced therefrom. For the procedures, references are made to standard manuals. From the demonstration of the calculation of the formula, the question of isomerism and the necessity for structural formulas are developed and the theory of linkages briefly treated. Much space is given to the writing of structural formulas. The section on alcohols is followed by one on the immediate derivatives, and the text then takes up petroleum. In this manner the discussion proceeds until all the great groups of organic chemistry are treated. There is a

very large amount of modern chemistry in the book, very carefully and accurately set forth. Whether the general method will prove entirely satisfactory in practice cannot be stated as yet. The sub-title, "A Brief Introductory Course," challenges argument, but only wide use will determine whether the book has real advantage over the more formal and carefully systematized manuals generally in vogue.

A commendable feature is the stress laid upon interpreting organic formulas, on the tri-dimensional system. This should be frequently used by both teacher and pupil. There is far too little use of models in the teaching of organic chemistry. The presentation of the theories of the composition and relations of organic bodies as set forth in this book contrasted with similar data in inorganic manuals shows how much two branches of descriptive chemistry are apart in their pedagogic phases.

In a future edition, more prominence should be given to the use of the name "methanol" for methyl alcohol, in pursuance of the wish of sanitarians to eliminate the term "alcohol" from the name of the substance. It also seems to the reviewer that it is an error to speak of racemic acid as a form of tartaric acid. Whether this acid is considered theoretically as a "racemic mixture" or a "racemic compound" it is, after all only the two active tartaric acids in association. The older chemists will be rather astonished to learn that in modern parlance the letters "*d*" and "*l*" applied to carbohydrates, do not refer to the direction in which polarized light is turned, but to the spatial relations of the groups. Hence levulose though levorotatory is termed *d*-fructose. Truly the world moves. On page 128 it is stated that chloroform for anesthesia must be pure, but the U. S. P. requirement is that it should contain not less than 0.6 per cent. of alcohol. This greatly retards decomposition.

HENRY LEFFMANN.

"THE NEW REFORMATION" (FROM PHYSICAL TO SPIRITUAL REALITIES). By Michael Pupin, of Columbia University. XVII–273, pages, 12mo., cloth, New York, Charles Scribner's Sons, 1928. Price, $2.50.

If Dr. Pupin were an athlete, he would have what Jack Dempsey in boxing and Jean Borotra in tennis possess—that is, "colorfulness." As a scientist, this power of making a popular appeal may be at once an asset and a liability to him. He undoubtedly gets his fine personality across to his readers. But does he, at the same time, lose any of his splendid prestige as a hard-headed man of science? We are inclined to think that he does not.

Our first impression of this book was that it represented another structure, similar to those reared by Henry Gordon Drummond in his "Natural Laws in the Spiritual World," Dr. W. W. Keen on "Evolution and Christianity," and by Joseph Le Conte (1826–1902) the brilliant geologist in his "Religion and Science" and "Evolution and Its Relation to Religious Thought" (many other scientists have done the same) and employing scientific principles upon which to compose statements of religious faith.

Dr. Pupin does indeed do this but he has the advantage of the greater store of information offered by the scientific achievements of recent years and he has the rare gift of combining "close thinking" with a high degree of human interest.

We would not disparage the arguments of the other authors mentioned when we state that, in our belief, Pupin has not merely produced "just another book"

but has given us one that for a long time to come will hold a commanding place in the field of "Intrascience" (the science within science); and will be read more than once by the person competent to perceive its significance.

Every scientist, without a doubt, has in his own mind a fairly definite idea of what is meant by the "scientific method," although the verbal expression of the idea might vary from that given by others. For example, Baker Brownell (a philosopher, not a scientist) considers science to be the product of "sensation and reason," whereas Pupin defines it as "observation, experiment and calculation." The latter is, of course, the more careful definition.

Pupin goes further and endeavors to disclose the inner spirit of true science when he writes:

"Humility was not always a cardinal virtue of religious reformers, but it was such a virtue of men with a truly scientific mental attitude. In the presence of God's eternal truth they humbly bow down and cheerfully accept any place which that truth assigns to them."

Dr. Pupin's book is unusual in many ways. He has no table of contents. He writes a Prologue and declares the seven sections which follow to be not chapters but "narratives." These are the titles:

"I. The Awakening of Scientific Individualism;
II. The Physical Reality of Matter in Motion;
III. The Physical Reality of Electricity in Motion;
IV. The Physical Reality of Electrical Radiation;
V. Granular Structure of Electricity and of Radiation;
VI. From Chaos to Cosmos;
VII. Creative Co-ordination."

The author outlines his purpose thus:

"It is hoped that by strengthening our understanding of the physical realities the narratives will reform our mental attitude and make it better prepared for the recognition of the truth that physical and spiritual realities are the fruit of the same tree of knowledge, which was nurtured by the soil of human experience."

Emphasis is laid upon the granular structure of electricity and radiation and the thought is advanced that living cells in organic life and human beings in society might similarly be regarded as "granules."

The Columbia University Professor presents a new concept which he names "Creative Co-ordination;" drawing the picture from a review of Carnot's law of action of the moving power of heat. Pupin writes:

"Just as the steam-engine co-ordinates the non-co-ordinated activity of the erratic molecules of the hot steam, so the galvanic cell is a co-ordinator of the non-co-ordinated chemical activity of the atoms and molecules of the metals and fluids in the cell."

We quote further:

"The physical life of man is the highest product of this creative co-ordination; to transform the life of humanity into a cosmos, a life of simple law and beautiful order, is the highest mission of human life in its broadest aspect. Can it perform this mission by the revelation of physical realities only? No, it cannot; it must search for other realities which are today outside of the domain of physical science."

Then the author applies the concept to organic life where he finds the living cell is the "creative co-ordinator:" and then to the world of consciousness in which he suggests that "Love, according to Christ," is the most powerful of these "co-ordinating forces."

"Just as the cosmic processes of creative co-ordination guide the evolution of the external material world," he asserts, "so creative co-ordination also guides the evolution of the internal world of the human soul, the destiny of human life. This is my message from science."

These passages also deserve especial attention:

"This (Newton's deductions) is the revelation which conveyed to man the joyful message that nature in every part of the universe, as revealed by the motions of heavenly bodies, is intelligible, and that she employed the same simple language and logic when she spoke to Archimedes in the baths of Syracuse, to young Galileo in the Cathedral of Pisa, and to Tycho Brahe and Kepler, when, with a watchful gaze, they recorded and scrutinized the paths of the planetary wanderers in the distant depths of heaven, an ideally simple message describing an ideally simple material universe."

"The mental attitude of man is often controlled by countless tiny motions; it is as immovable as the stump of an ancient oak which grips the soil with countless tiny roots. Nothing illustrates better the inertia of the mental attitude of Christian theology and that of science."

Then there is an Epilogue which many would cite as one of the best sermons ever written.

JOHN W. STOCKWELL.

PUBLICATIONS RECEIVED.

The Electrical Conductivity of the Atmosphere and Its Causes, by Victor F. Hess, Ph.D. 204 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1928, price $4.00.

The Fundamentals of Human Motivation, by Leonard T. Troland, Ph.D. 521 pages, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $5.00.

The Falls of Niagara, by Glenn C. Forrester. 155 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $2.50.

Radio. A Study of First Principles for Schools, Evening Classes and Home Study, by Elmer E. Burns. 255 pages, illustrations, 12mo. New York, D. Van Nostrand Company, Inc., 1928, price $2.00.

Practical Television, by E. T. Larner. 175 pages, illustrations, plates, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $3.75.

Organic Chemistry. A Brief Introductory Course, by James Bryant Conant. 291 pages, diagrams, 8vo. New York, The Macmillan Company, 1928.

Balistique Intérieure Théorique et Tables Numeriques, by G. Sugot. 130 pages, diagrams, tables, 8vo. Paris, Gauthier-Villars & Cie, 1928, price 40 fr.

Balistique Extérieure Théorique, by G. Sugot. Pages 828 to 920, illustrations, 8vo. Paris, Gauthier-Villars & Cie, 1928, price 25 fr.

Code for Electricity Meters, prepared by a Sectional Committee according to the procedure of the American Engineering Standards Committee under the joint sponsorship of the Association of Edison Illuminating Companies, National Electric Light Association, United States Bureau of Standards. Third Edition. Approved as American Standard by the American Engineering Standards Committee, February 20, 1928. 122 pages, 8vo. New York, National Electric Light Association, 1928, price $2.00.

Ice Engineering, by Howard T. Barnes. 364 pages, illustrations, 8vo. Montreal, Renouf Publishing Co., 1928, price $5.00.

National Advisory Committee for Aeronautics. Technical Notes No. 291, Gluing practice at aircraft manufacturing plants and repair stations, by T. R. Truax. 11 pages, plate, quarto. No. 292, The drag of a J-5 radial air-cooled engine, by Fred E. Weick. 4 pages, plate, quarto. No. 293, The formation of ice upon exposed parts of an airplane in flight, by Thomas Carroll and Wm. H. McAvoy. 10 pages, plate, quarto. Washington, Committee, 1928.

Solubilities of Inorganic and Organic Compounds, by Atherton Seidell, Ph.D. Supplement to the Second Edition. Pages 1001 to 1569, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $8.00.

CURRENT TOPICS.

Differential Intensity Sensitivity of the Ear for Pure Tones. R. R. Riesz. (*Phys. Rev.*, May, 1928.) No one doubts the technical value of telephone engineering but in pure physics it plays an important rôle in preventing the disappearance from journals of articles dealing with sound. The communication engineer needs to know the smallest change in intensity that the human ear can detect. "This information is also of interest to physicists when considering the ear as a physical instrument, to psychologists in formulating relationships between exciting physical stimulus and the resulting sensation and to otologists in the study of normal and abnormal hearing." In 1923 the *Physical Review* published Knudsen's results on this subject which have constituted the best available source of information up to the present but they did not cover the entire range of intensities and frequencies for which the ear is sensitive. This investigation embraces practically the complete range.

The quantity measured in these experiments is the ratio of the smallest possible increment in the intensity of sound that the ear can perceive to the total intensity of the sound. Here this fraction will be designated "differential sensitivity" though it is called also Weber's constant, Weber-Fechner ratio, and intensity sensibility. The differential sensitivity of twelve normal observers was studied for frequencies ranging from 35 to 10,000 cycles per sec. and for intensities from the threshold of audition to the threshold of feeling. The changes of intensity studied were obtained by sending through a special telephone receiver two alternating currents simultaneously, their frequencies being so nearly alike that beats were produced, while the two resulting tones differed too little in pitch to complicate the observations. A preliminary study showed that the differential sensitivity depends upon the interval of time between the production of the two sounds whose intensities are to be compared. For 1,000 cycles per sec. the differential sensitivity was a minimum in the vicinity of 3 beats per sec. This number of beats was therefore selected as the normal one for use.

Two vacuum tube oscillators produced alternating currents of any specified frequency. The two currents passed through voltage attenuators, then through an electric filter to remove harmonics and thence to the telephone receiver of special construction. One

oscillator was set at some frequency and the other at such a frequency as to give three beats per sec. One of the currents from an attenuator was fixed at a certain voltage and the voltage from the other varied until beats became just audible. From the theory of beats and the relation between impressed voltage and intensity it is possible to calculate the differential sensitivity for the frequency and intensity in this case. "Complete series of measurements were made on twelve male observers at frequencies of 35, 70, 200, 1,000, 4,000, 7,000, and 10,000 cycles per second and at intensities from weak tones near the threshold of audition to very loud tones near the threshold of feeling." The curves representing the results show "that at any given frequency the differential sensitivity approaches a constant value for high intensities but increases rapidly as the intensity is reduced toward the auditory threshold." No matter what the frequency the differential sensitivity is about the same for all intensities 1,000,000 or more times as great as the minimum intensity affecting the ear. If tones of different intensity are investigated it is seen that in all cases the differential sensitivity is least for about 2,500 cycles per sec., that is, for this frequency the ear can detect the least change of intensity. "At 1,300 cycles per second the ear can distinguish the greatest number of tones as being of different intensity, that number being 370." G. F. S.

Experiments on the Diffraction of Cathode Rays. G. P. THOMSON. (*Proc. Roy. Soc.*, A 778.) According to de Broglie's theory of mechanics a particle in motion acts as a group of waves whose velocity and wave-length can be calculated from the mass and velocity of the particle. This velocity of the waves is greater than the velocity of light, but the Theory of Relativity is not thereby violated because the waves are geometrical conceptions and do not carry energy. "The consequences of this theory have been worked out by de Broglie, Schroedinger and others and applied to problems in spectroscopy where they have provided the solution of several outstanding difficulties left by the older theory of orbits. In view, however, of the extremely fundamental nature of the theory it is highly desirable that it should rest on more direct evidence, and, in particular, that it should be shown capable of predicting as well as of merely explaining." The work of Davisson on the reflection of electrons from the surface of crystals is of great importance in this connection. ("Are Electrons Waves?" Davisson. JOURNAL OF THE FRANKLIN INSTITUTE, May, 1928.) In the present paper the author recounts his quest for an effect of crystals upon electrons that shall resemble the diffraction of X-rays by crystals.

For electrons that have fallen through a potential difference of 25,000 volts to gain their velocity the length of the equivalent waves is about 0.75×10^{-9} cm. "This is of the order of that of hard X-rays and the waves associated with electrons of this energy should behave in many respects like hard X-rays. In particular the electrons should show diffraction effects when passed through a crystal identical with those shown by X-rays of the same wave-length. It is, perhaps, hardly necessary to say that this does not mean that the two are indistinguishable. Unlike X-rays the electrons are deflected by electric and magnetic fields. They carry a charge, and for equal wave-lengths, have much less energy and less penetrating power." In the experiment a beam of cathode rays, that is, of electrons, fell through voltages ranging from 12,000 to 61,200 and passed through a tube of fine bore into a chamber maintained at a low vacuum. The application of a magnetic field showed the beam to be nearly homogeneous. In the chamber it fell at normal incidence upon thin films made up of crystals and, emerging, was received by a photographic plate 32.5 cm. behind the film. If the film consists of crystals with random arrangement one type of pattern should be imprinted on the plate. If, on the other hand, there is a somewhat orderly arrangement of the crystals a modified pattern will appear. Both cases were actually observed. The main difficulty encountered was to get films so thin that the electron was scattered only once in traversing it. Of aluminium "the films used were the thinnest foil etched down by floating in caustic potash until they were transparent." The maximum thickness for good results was about 10^{-5} cm. Gold films were made thin by aqua regia and a film of celluloid 5×10^{-6} cm. in thickness also was used. Reproductions of the patterns obtained are given. "In all cases the general effect is that of a series of concentric rings round the spot made by the undeflected beam. In some cases these rings are uniform round the circumference, in others the intensity is more or less concentrated in a series of spots on the circumference." The patterns are much like those produced by X-rays in the "powder" method. The dimensions of the rings should vary with the velocity of the electrons, if they are due to diffraction. In the case of both aluminium and gold the diameters of the rings changed as the voltage was varied and, more than that, followed in their changes a relation derived from de Broglie's theory. Moreover when the side of a unit cube of these metals is computed from the data of the experiment it comes out in both instances within about one per cent. of the value obtained from the diffraction of X-rays.

These experiments on diffraction following as they do those of

Davisson on reflection go far to show that there is a real physical basis for the wave theory of mechanics. G. F. S.

The Specific Heats of Ferromagnetic Substances. L. F. BATES. (*Proc. Roy. Soc.*, A 778.) Pierre Weiss, now of the University of Strasbourg, on the basis of his theory of the internal molecular field predicted that ferromagnetic substances should show discontinuities in their specific heats near the temperatures at which they change into paramagnetic substances. He and his collaborators conducted experiments on the specific heats of nickel, iron and magnetite that afforded at least partial confirmation of the prediction. In Great Britain Sucksmith and Porter examined nickel and Heusler alloy. Their results were not in agreement with Weiss' theory because the change in the specific heat was not limited to the temperature at which the magnetic properties practically disappeared but was spread out over a considerable range of temperature. The existence of a group of manganese compounds, the phosphide, arsenide, antimonide and bismuthide, magnetic in character and having critical points at 26°, 45°, 330°, and 380° respectively renders it possible to institute a fresh investigation with none of the difficulties due to the employment of high temperatures. MnAs was prepared according to the directions of its discoverers, Hilpert and Dieckmann. The relation of its magnetic properties to temperature was examined. "The substance ceases to be ferromagnetic in the neighborhood of 45° C. If, however, the temperature is reduced after the specimen has been rendered paramagnetic, it is seen that the induction changes but slightly until a temperature between 33.5° and 34° is reached, when the substance rapidly regains its ferromagnetic properties."

The calorimetric method consisted in supplying heat slowly to the powdered arsenide by an electric current flowing through No. 42 manganin wire, the temperature being read at the same time from the resistance of another coil in the powder. 8912 seconds were needed to raise the temperature from 25.5° to 53.8° C. "The specific heat rises slowly from a value of 0.122 at 28° C., to a value of 0.14 at 36° C., then rises with increasing rapidity to a value of about 0.8 in the neighborhood of 42° C., then falls rapidly to a value of 0.13 at 45° C., and thence to a slightly defined minimum value of 0.10 at 46.5° C., after which it slowly rises with increase of temperature."

The relation between the temperature of the arsenide and its induction in a strong magnetic field was studied. When a curve is plotted connecting temperature with rate of change of induction with temperature it is found to have a close resemblance to the

specific heat-temperature curve. The maxima of the two curves occur at the same temperature.

The author calculates that the addition of 1.79 calories per gram is required to transform the ferromagnetic arsenide into its paramagnetic form. The results of the investigation seem to confirm Weiss' theory. G. F. S.

From the Physical Laboratory of the University of Utrecht comes an interesting determination of the rate of production of quanta of light in a sodium flame. It is found that each atom emits in a second 250 quanta when the temperature is 1,970° C. (*Ann. d. Physik*, No. 7, 1928.) G. F. S.

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AN ATTEMPT TO DETECT A MAGNETIC FIELD AS THE RESULT OF THE ROTATION OF A COPPER SPHERE AT HIGH SPEED.

BY

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Communication No. 29.

Introduction: One type of magnetic field attributable to rotation is well known from the investigations of S. J. Barnett. It arises from the gyroscopic action of the rotation of the electron orbits of the atom which are responsible for the magnetic properties of the substance, and is zero when the intrinsic magnetic moment of the atom is zero. We shall refer to this effect as the Barnett effect. It is not this effect with which we are concerned in the investigation to be described, but rather with the possibility of the creation of a magnetic field as a result of causes of even more subtle nature, causes not included in our scheme of classical electrodynamics.

The possibility of producing a magnetic field by pure rotation of neutral matter finds one of its chief fields of interest in connection with attempts to explain the origin of the

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earth's magnetic field. The Barnett effect is inadequate for this purpose even though we should assume the earth to be made entirely of iron, for it would account for a magnetic field only 10^{-10} of the earth's magnetic field.

Almost any theory of the origin of a magnetic field as the result of rotation of a neutral sphere makes the field depend upon the density of the material, the angular velocity, and the radius of the sphere. In a recent paper [1] it has been shown by one of us that, if we confine ourselves to an expression of the magnetic field involving only the product of simple powers of the angular velocity and radius, knowledge of the magnetic fields of the earth and sun, and of the fact that the magnetic field of a small body rotating at high but attainable speed is not so large as to have forced itself upon our observations long ago, are sufficient to limit us to two possible expressions for the magnetic field at the surface of the sphere. According to one of them, the field at the surface is proportional to $D\omega a^2$ and according to the other it is proportional to $D\omega^4 a^4$, where D is the density, ω the angular velocity, and a the radius of the sphere. The values predicted by these two possibilities for the magnetic field H_z at the pole of the Sun and at the pole of a copper sphere 10 cms. in radius rotating 200 times per second, are given in Table 1,

TABLE I

Current Density Proportional to	Form of H_z	H_z Gauss		
		Sun	Earth	Copper Sphere 10 cms. in Radius, Rotating at 200 revs. per sec.
$D\omega r$	$AD\omega a^2$	58	0.5	3.2×10^{-9}
$D\omega^3 r^4$	$AD\omega^4 a^4$	42	0.5	4.4×10^{-3}

A being a constant. The constant of proportionality A is adjusted to give the value 0.5 gauss at the earth's pole. The detailed development of these possibilities present the matter in a light in which the sphere acts as though currents circu-

[1] W. F. G. Swann, "A Generalization of Electrodynamics, Consistent with Restricted Relativity and Affording a Possible Explanation of the Earth's Magnetic and Gravitational Fields, and the Maintenance of the Earth's Charge," *Phil. Mag.*, S. 7, Vol. 3, pp. 1088–1136, 1927.

lated about the axis of rotation. The apparent current density depends upon the angular velocity and the distance from the axis of rotation. Corresponding to the first of the possibilities cited, the apparent current density i is proportional to $D\omega r$ and according to the second, it is proportional to $Dr^3\omega^4$.

The former of these possibilities would give for the small sphere a field far below the limits of measurement while the latter gives a value which is measurable, though with some difficulty. Since it is not practicable to measure the field at the surface, use was made of the expression from which the field 4.4×10^{-3} given at the surface was obtained, for calculating the field at places in the vicinity of the sphere where it could be measured.

The expression for the magnetic potential Ω in electromagnetic units, and due to the sphere, is[2]

$$\Omega = \frac{-8}{35C} A\pi D\omega^4 a^4 \left\{ \frac{2}{3} P_1(\theta) \frac{a^3}{R^2} - \frac{1}{9} P_3(\theta) \frac{a^5}{R^4} \right\}, \qquad (1)$$

in which the current density has been written as $i = AD\omega^4 r^3$, where a is the radius of the sphere, R the radius vector to the point at which Ω is sought, θ is the angle made by this radius vector with the axis of rotation, and the P's are the Legendre polynomials. C is the velocity of light.

The values of the magnetic fields, H_R parallel to the radius vector, H_θ perpendicular to the radius vector, and H_r perpendicular to the axis of rotation, are, respectively:

$$H_R = \frac{-32}{35C} A\pi D\omega^4 a^4 \left\{ \frac{1}{3}\frac{a^3}{R^3} P_1(\theta) - \frac{1}{9}\frac{a^5}{R^5} P_3(\theta) \right\}, \qquad (2)$$

$$H_\theta = \frac{-8}{35C} A\pi D\omega^4 a^4 \left\{ \frac{2}{3}\frac{a^3}{R^3} \sin\theta - \frac{5}{9}\frac{a^5}{R^5} P_2(\theta) \sin\theta \right\}, \qquad (3)$$

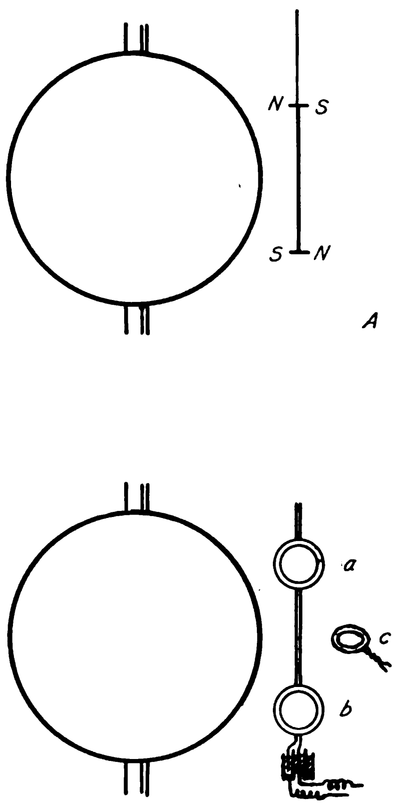
$$H_r = \frac{-8}{105C} A\pi D\omega^4 a^4$$

$$\times \left\{ 6\frac{a^3}{R^3} \cos\theta \sin\theta - \frac{1}{3}\frac{a^5}{R^5} (3\cos\theta + 7P_3(\theta)) \sin\theta \right\}. \qquad (4)$$

[2] See "A Generalization of Electrodynamics, etc.," *Phil. Mag.*, S. 7, Vol. 3, pp. 1088–1136, 1927. By replacing I by $AD\omega^4\sigma^3 \sin^3 \beta\sigma d\beta d\sigma$ in the first expression on p. 1116 of this paper, and then integrating from $\sigma = 0$ to $\sigma = a$, and from $\beta = 0$ to π, equation (1) given above will readily be obtained.

Experimental Arrangement: For the detection of the magnetic field, an astatic magnetometer is the instrument which naturally suggests itself, the two magnets of the astatic system being supported symmetrically with respect to the equator of the sphere as shown in Fig. 1, *A*. The sphere would then act in an additive manner on the two elements of the astatic system; while the system would be astatic as regards uniform magnetic fields such as that of the earth. This arrangement was used in preliminary experiments; but, with a copper sphere 10 cms. in radius, rotating 200 times per

Fig. 1.



second, it is difficult to reduce vibrations to an extent which renders practicable the use of a system of this kind. For this

reason, we resorted to an astatic earth inductor compass, arranged as in Fig. 1, *B*. The coils *ab* rotated about a vertical axis. They were wound in opposite directions, so that they were additive in their effects as regards the magnetic field of the sphere, but subtractive as regards any uniform field such as that of the earth. The coils were connected through mercury contacts to an amplifier, which operated a Leeds & Northrup alternating current galvanometer. The current to the field coils of the galvanometer was supplied by a small generator which was driven on the same shaft as the earth-inductor compass, but at a distance of about 2 m. from the compass. The axis of the coils was placed as near as possible to the rotating sphere; and, the distance between the coils was then chosen so that the value of H_r calculated for the center of one of the coils was a maximum.

In order to standardize the readings of the galvanometer, use was made of a small coil *C*, Fig. 1, *B*, of radius 1 cm., and with 18 turns, situated with its plane horizontal and its center in the plane of the axes of the sphere and compass and at a distance of 2.8 cms. from the axis of the compass, on the side remote from the sphere. The horizontal field component due to such a coil is:

$$H_r = \frac{3\pi N}{20} I \frac{b^2}{R^3} \sin 2\theta \left[1 - \frac{5}{8}\frac{b^2}{R^2} (7 \cos^2 \theta - 3) \right],$$

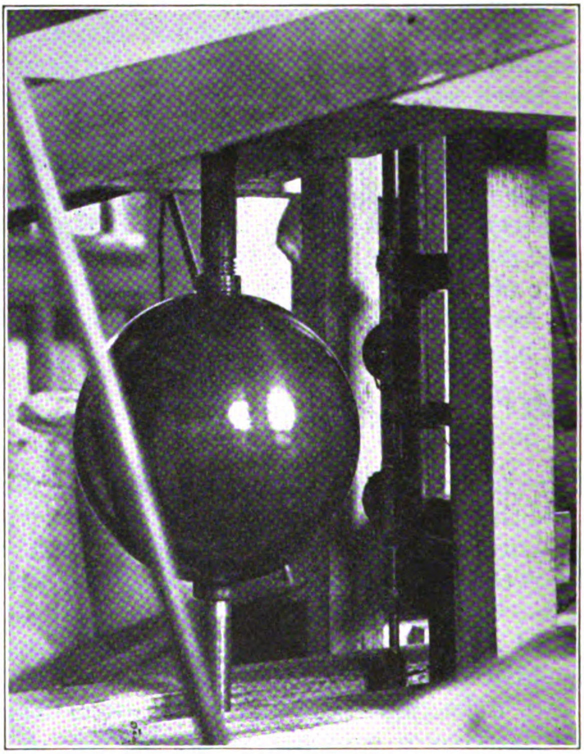
where *I*, the current in the coil is in amperes, *N* is the number of turns, *b* is the radius of the coil, *R* the radius vector to the point at which the field is derived, and θ the angle made by the radius vector with the axis of the coil. The galvanometer deflection due to a known current in this coil served to determine the field at the center of one of the earth-inductor coils, and so provided a means of reducing to absolute measure the galvanometer deflections obtained in the main experiments.

The earth-inductor compass was rotated by a belt and pulley attached to a small motor situated at a distance of about 5 m. from the sphere, and the sphere itself was rotated by means of a friction drive made of non-magnetic parts, and driven by a 2.5 horsepower motor situated at a distance of 5 m. from the sphere. The plan adopted was to spin the sphere up to speed, disconnect it from the friction drive by

means of a clutch, stop the motor, and then take readings as the sphere died down in speed.

Quite apart from any magnetic field of the type sought in this investigation, we have, of course, a magnetic field arising from Foucault currents generated by the sphere rotating in the earth's magnetic field. By considering the nature of the Foucault currents generated in a rotating sphere,[3] it is easy to see that such currents would cancel as regards

FIG. 2.



their magnetic effects on the earth-inductor compass in the case of a sphere rotating in a uniform field, and with the center of the compass in the equatorial plane of the rotation.

[3] J. J. Thomson, "Recent Researches in Electricity and Magnetism," pp. 546–557.

It is, however, impracticable to produce and maintain with certainty a condition of symmetry satisfactory for compensation in this manner, and, consequently the sphere was surrounded by a pair of Helmholtz coils which were adjusted so as to annul the earth's field.

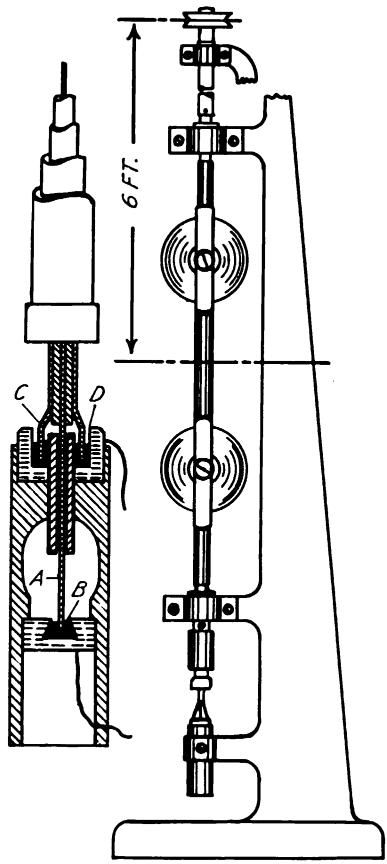
FIG. 3.

Fig. 2 shows the copper sphere, 10 cms. in radius, which was used in the experiment. It was necessary to balance it very carefully before use. Fig. 3 is a picture of the sphere with its friction drive mounted in position with the Helmholtz

coils. The sand bags were not an unnecessary precaution when it is realized that the sphere increased in equatorial diameter by 2.4 mm. after rotation to a speed of 200 revolutions per second. The wooden frame shown in the upper portion of Fig. 3 carries the shaft of the earth-inductor compass. The coils of the compass itself are not visible in the picture.

Fig. 4 shows a more detailed picture of the coils and com-

FIG. 4.

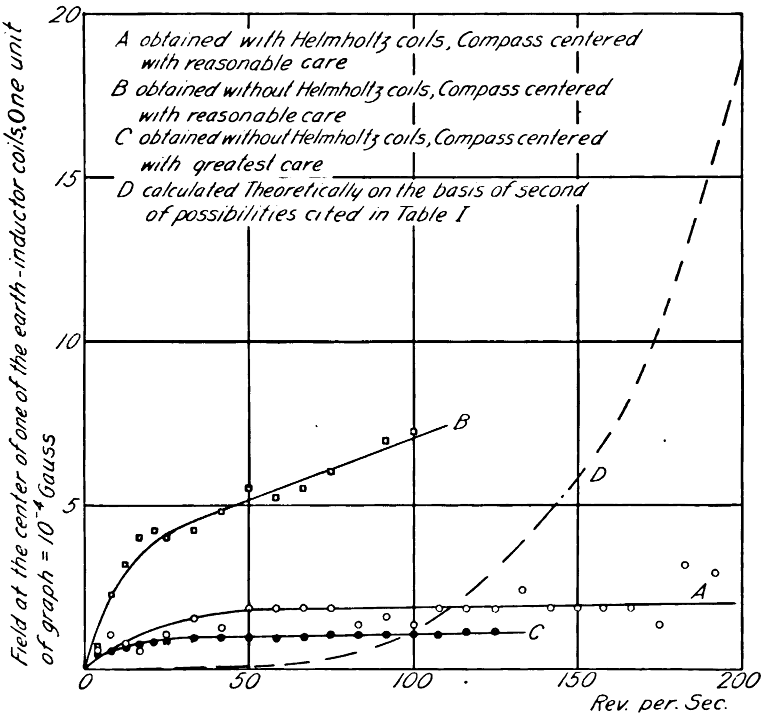


mutator. One end of the coil system was attached to the metal rod A, which rotated in the mercury cup B. The other end was attached to the thin copper cylinder C which rotated

in the mercury cup *D*, which formed an annulus concentric with the cup *B*. Hard rubber formed the mounting for the cups, and a hard rubber tube separated *A* from *D*. The resistance of the two earth-inductor coils was about 600 ohms; and, with the commutator as described, was the same under rotation as at rest.

The use of an alternating current galvanometer in conjunction with an amplifier calls for attention to many details if one is to interpret properly the relation between the input and output. However, in the present instance, all uncertainty in this connection was avoided by the process of calibrating the system under its working conditions by means of the coil *C*, Fig. 1, *B*.

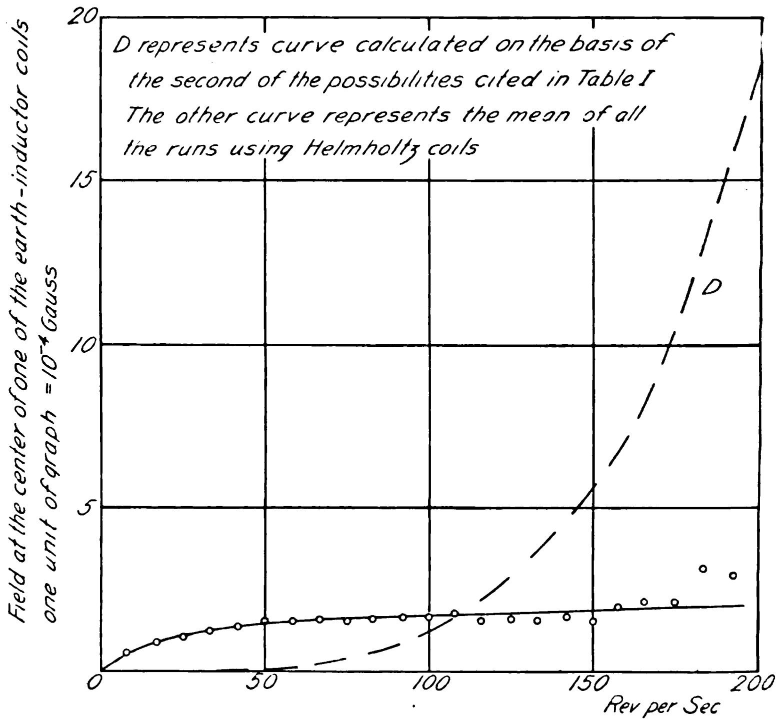
FIG. 5.



The Results: Figs. 5 and 6 give the results obtained, the ordinates representing the field intensity at the center of one of the earth-inductor coils, and the abscissæ representing the

speed of rotation. Curve *B*, Fig. 5, gives the results obtained in the absence of the Helmholtz coils, and with the earth-inductor coil centered with no special care. Curve *A*, Fig. 5,

Fig. 6.



was obtained using the Helmholtz coils. It shows very clearly that the results for curve *B* had their origin in the earth's magnetic field. The approximation to a saturation effect in curve *B* arises, of course, from the shielding action which the Foucault currents themselves exert. That the results obtained in curve *B* have no connection with the effect sought in the present experiment is further borne out by curve *C*, Fig. 5, which was taken without Helmholtz coils, but with the earth-inductor compass centered as carefully as possible. We do not attach any special significance to the fact that the curve *C* lies lower than curve *A*, as imperfect centering of the earth-inductor compass may, in the presence of the earth's

field, cause deflections either positive or negative, depending upon the nature of the lack of symmetry.

Curve *D*, Fig. 5, represents the results which would have been obtained upon the basis of the second of the possibilities cited in Table 1, viz., that in which the apparent current density is proportional to $Dr^3\omega^4$, the factor of proportionality being adjusted so as to result in 0.5 gauss for the pole of the earth. The curve *A* obtained with Helmholtz coils thus corresponds to a field only about one-ninth of that calculated for a speed of 200 revolutions per second on the basis of the above formula. One is naturally tempted to inquire as to what the residual field represented in curve *A* may correspond to. It disappears when the sphere is removed, and only the shaft and the remainder of the apparatus is in operation. Thus, it owes its origin to the sphere. It was found possible to produce a spurious effect of this kind by placing a finger on the shaft of the earth-inductor compass, so as to cause a slight distortion of the axis. It is clear that very slight relative alterations of the planes of the coils of the compass during a run would serve to give quite large effects unless the magnetic field of the earth were compensated absolutely. It is thought that this effect may arise from the presence of the wind on the coils, resulting from the rapid rotation of the sphere.

Of course, a large number of runs were taken, and a list of all of them is given in Table 2. In each case the earth's field was balanced to about one per cent. of its value by means of the Helmholtz coils. The last column of the table gives the averages, for corresponding speeds, of the residual fields for all of the runs. In view of the fact that the number of runs at high speed was less than that at low speed the number of observations which contribute to the average gets less and less with increase of speed. The average values are plotted in Fig. 6, again with the theoretical curve *D* for comparison.

Experiments designed to measure the possible production of a magnetic field as the result of rotation were performed by P. Lebedew,[4] who used for the purpose a cylinder 3 cms. in radius and 6 cms. long. He rotated this cylinder up to 500 revolutions per second, and tested for a magnetic field by

[4] *Ann. der Physik*, **39**, p. 840, 1912.

TABLE 2.

Record of All Runs Using Helmholtz Coils.

The numbers under H, when multiplied by 10^{-4} give the field in gauss at the center of one of the earth-inductor coils.

Date	Mar. 10	Mar. 12	Mar. 13	Mar. 13	Mar. 13	Mar. 19	Mar. 23	Mar. 23	Mar. 23	Mar. 29	Mar. 29	Mar. 30	Apr. 2	Apr. 2	Apr. 2	Apr. 2	Average
Speed r.p.s.	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
200																	
192					2.92												2.92
183					3.19												3.19
175				2.9	1.33												2.12
166				2.4	1.86												2.13
158				2.1	1.86												1.98
150	2.56	1.63		1.6	1.86												1.53
142	2.26	1.63	1.3	1.3	1.86			1.79									1.69
133	2.42	1.40	1.36	1.6	2.40			1.22	.28								1.53
125	2.21	.47	1.86	1.6	1.86			.94	.47					2.02	2.64	1.90	1.60
116	2.21	.47	1.86	1.6	1.86			.66	.47					1.98	2.55	1.92	1.56
108	2.26	.47	2.9		1.86			1.13	.57		2.31			1.94	2.50	1.94	1.79
100	2.42	.70	2.1	1.6	1.33		2.58	1.03	.57	1.95	2.26	.86	1.51	1.90	2.46	1.92	1.68
92	2.72	.47	2.5	1.3	1.59		2.53	1.03	.57	1.89	2.21	1.12	1.14	1.86	2.46	1.74	1.68
83	2.36	.47	1.8	1.3	1.33		2.48		.47	1.89	2.15	1.72	1.06	1.82	2.38	1.66	1.64
75	2.21	.93		1.85	1.86	.30			.47	1.89	2.10	1.63	.87	1.81	2.36	1.70	1.54
67	1.96	.47	2.9	1.6	1.86	.78	2.48	.85	.47	1.78	2.00	1.63	.99	1.75	2.34	1.66	1.60
58	2.21	.47	2.9	1.6	1.86	1.20	2.53	.56	.47	1.73	1.94	1.59	−.20	1.71	2.27	1.66	1.53
50	2.21	.93	2.7	1.6	1.86	.90	2.48	.56	.47	1.73	1.79	1.55	0	1.61	2.18	1.60	1.51
42	2.26	.23	1.3	1.6	1.26	1.08	2.43	.47	.47	1.62	1.68	1.42	.08	1.50	2.04	1.55	1.35
33	1.06	.47	1.3	1.3	1.59	1.02	2.38		.47	1.51	1.52	1.33	0	1.38	1.91	1.45	1.25
25	.76	.23	1.3	1.1	1.06	.90	1.91	1.13	.47	1.35	1.37	1.25	.24	1.24	1.68	1.43	1.09
17	1.51		1.6	.2	.53	.84	2.10	1.22	.38	1.08	1.05	.95	.51	.97	1.38	1.23	.91
8	.30	.47	1.6	−.2	1.06	.30	1.81	−.28	.38	.60	.58	.47	0	.47	.79	.89	.58
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

means of an astatic magnetometer. His object was to test for a magnetic field which, at the pole of a sphere of radius a, would be proportional to $\omega^3 a^3$. No appreciable magnetic field was observed. His sensitivity was such that on the basis of the second type of law quoted in Table I, he would, for the most favorable case—that of his brass cylinder—have measured about 3 divisions on his magnetometer scale at the highest speed of rotation, 500 revolutions per second, whereas the sensitivity of our apparatus was such that, on the basis of the same law, the expected effect amounted to from 500 mm. to 70 mm., at 200 revolutions per second, depending upon the sensitivity adopted in the particular run concerned. The actual sensitivity of our earth-inductor compass varied in different experiments from 2.6×10^{-5} gauss per division to 0.4×10^{-5} gauss per division, while the sensitivity of the astatic magnetometer of Lebedew was 4×10^{-4} gauss per division, as estimated from the data in his paper. Neither in the experiments of Lebedew, nor in ours, would any measurable effect have been expected on the basis of a law of the first type quoted in Table I, with constant of proportionality adjusted to correspond to the earth's field.

It is worthy of note that, in expecting a correspondence between the form of the law for the conditions pertaining to the earth and those pertaining to a copper sphere, 10 cms. in radius, rotating 200 times per second, we are extrapolating over an enormous range. The situation may be illustrated by supposing that the apparent current density, instead of being proportional to $r^3\omega^4$ were proportional to $r^3\omega^{3.8}$. This very slight difference in the power to which ω is raised would result in an alteration of the field predicted for the small sphere from 43×10^{-4} gauss, to 1.5×10^{-4} gauss at the pole, and the latter field would not be measurable with the apparatus used. On the other hand, this small change in the form of the law would be negligible in its importance as regards comparisons of the magnetic fields of bodies such as the sun and earth, whose angular velocities are not of a totally different order of magnitude.

On account of the necessity for stability, the final experiments here recorded were performed at Swarthmore College instead of at the present temporary site of the Bartol Research

Foundation in Philadelphia. Our sincere thanks are due to Acting President John A. Miller for permission to use a laboratory at the College, also to Professor Winthrop R. Wright and Professor Andrew Simpson for the provision of facilities. Finally, we wish to acknowledge the efficient services of the chief instrument maker of the Bartol Foundation, Mr. Oscar Steiner, who made most of the apparatus and assisted in taking the measurements.

BARTOL RESEARCH FOUNDATION,
THE FRANKLIN INSTITUTE,
Philadelphia, Pa.

TOPOGRAPHY FROM THE AIR.*

BY

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WHEN the science of map-making from aërial photographs is considered from the viewpoint of its actual practical applications, it will be found that the problems arising therewith can be classed in a number of distinct groups. Each of these groups is independent from the others to the extent that any solution of the problems in one group may be combined with any solution of the problems of either of the other groups to accomplish the final purpose of constructing a topographic map by means of the data furnished by aerial photography.

In their rational sequence these groups are the following:

1st. The production of aërial photographs.

2d. The determination of the position of the focal plane of each of the photographs with relation to the earth.

3d. The conversion of the views as originally exposed to their equivalents in a horizontal plane of projection.

4th. The assembling of a traverse from the separate views to one aggregate area for the horizontal control.

5th. Construction of the contour lines.

6th. Converting the central or conical projection of the photographic views to orthogonal projection of the map.

7th. Drawing and reproduction of the actual map.

A discussion of all solutions which have been proposed in each of these groups, and many of which are in practical use, would lead far beyond the time limits available and it will therefore be necessary to deal with some selected ones of special interest on account of their adaptability to conditions found in this country.

Taking them up in the order just stated, we at once realize that aërial photographs must necessarily be made from suitable aircraft. The lighter-than-air craft, desirable as it may

* Presented at a Meeting held Thursday, February 23, 1928.

be from the viewpoint of steadiness of motion, is ruled out on account of its cost of operation, which would have made aërial topography too expensive to ever have become a com-

FIG. 1.

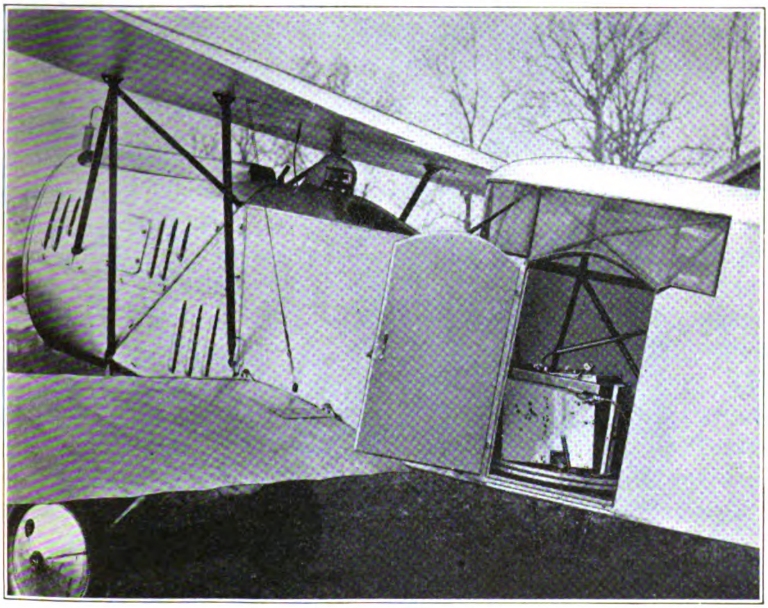
The photographic air-ship.

mercially sound industry. There remains thus the aëroplane, which, strange as it may appear, has until quite recently been constructed with an almost complete disregard for the special features required to effectively expose a series of views suitable for mapping purposes. Among the various types of aëroplanes, those suitable from the viewpoint of carrying capacity, operating space, ceiling, flying speed and landing speed, none were quite satisfactory as to the visibility afforded the pilot to steer his machine with the necessary certainty and precision over the lines of flight he is to follow. Whereas in general it is feasible for a well-trained pilot to follow the first of a series of flight directions, attempts to make further flights parallel to the first and at a predetermined distance were always highly uncertain on account of the impossibility of the pilot's seeing the actual course of his ship over the ground, however, recently a new design of aëroplanes has

been perfected, in which this peculiar difficulty has been satisfactorily overcome.

As to the stability of the camera, no matter if the photographic mapping process uses vertical, oblique or horizontal pictures, (for which designations the position of the lens axis is the determinant factor), it is essential that the exact position of the focal plane be known before further use can be made of aërial photographs for map-making.

FIG. 2.



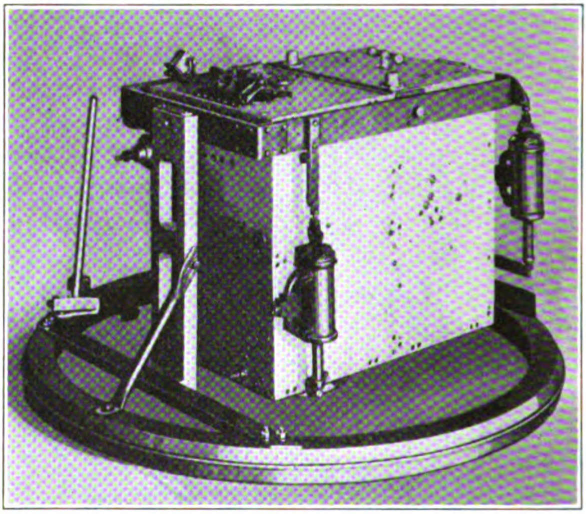
The Brock camera mounted in the airplane.

At first many attempts were made at stabilizing the camera, with relation to the earth, but thus far no really effective solution has been found along this line and hence the question arises, when given an aërial view, how can its plane of projection and the location of its viewpoint in space be reconstructed from the view itself, from the only actual information we have about it, viz: the focal length of the lens which made it and the position of this lens relative to the view. This brings us to the second group of problems:

the determination of the position of the focal planes of a series of views with relation to the earth.

In as much as this group of problems presents probably the most important one among the strictly theoretical questions in consideration, it has received attention from a large number of workers in this line of endeavor, with the result that several solutions have been offered. They may be classed in two main divisions; the first seeks to determine for each

Fig. 3.



The Brock camera on its turn-table.

view its true position by comparison of the view itself with the territory it depicts; that is, a comparison of some of the image points with the actual object points to which they correspond. The general principle underlying this class of solutions is based on what is known as projective relationship. This exists whenever rays proceeding from certain image points through the focal point of the lens all pass through their respective object points, in the reverse direction in which they proceeded from the object points to the image points at the time of exposure.

The actual image plane position can be correctly repro-

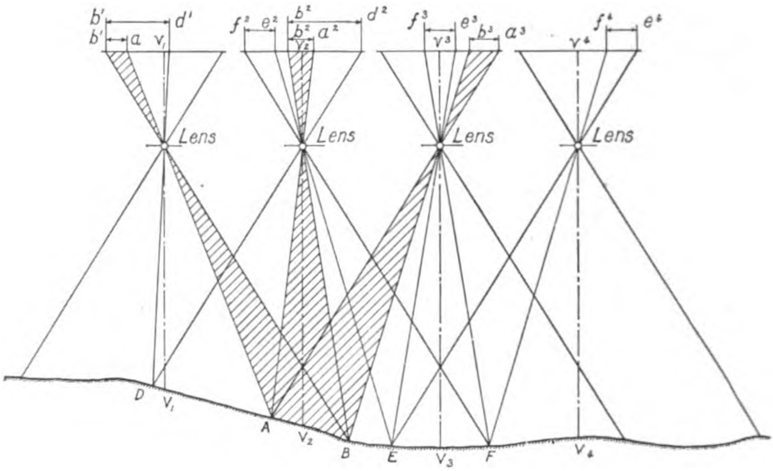
duced in this manner when the drawing containing the points representing the original object points is correct. It is necessary to have such a drawing in convenient scale, as it is manifestly impossible to use the actual object points themselves. Making such a scale drawing involves the measurement of the three space coördinates of each one of the ground points to be located on the drawing. At least four points per view are required to determine perspective relationship with certainty, as three points are frequently insufficient to avoid indeterminate values. This procedure requires thus a large amount of field surveying, unless the required data may be obtained from existing maps of sufficient reliability. Evidently in this instance the resulting air-survey map will not be more precise than the one from which the control data have been taken.

Many European countries possess maps which are deemed of adequate precision to be so used, but in the United States similar data of sufficiently dependable character are in existence in very rare instances only. It became, therefore, expedient to avoid this method of direct comparison of each separate view, and to look for means whereby the position of the focal plane of the several views can be established without the need of such extensive ground survey. The search for a method, which, while theoretically correct would at the same time be free from prohibitive expense for gathering field data, resulted in the Brock process, now being operated by the firm of Brock and Weymouth, Inc. of Philadelphia. Their method belongs to the second class in this group, in accordance with which aërial views are compared pair-wise with each other, instead of one by one with the ground. The stereoscopic relation between adjoining overlapping views forms the criterion whereby the true position of each view is determined. The Brock process uses, therefore, vertical views, that is to say, views made with vertically downward-pointing lenses on horizontal focal planes. Although the exposures are made as nearly as possible with correctly vertical lens axis, that condition is practically never realized and even if it were accomplished, it will only be found to be so by the same tests which indicate how much the deviation from verticality has been. The only difference is that the

answer will be zero instead of the usual deviation of a few degrees or some minutes.

The use of levels to indicate the position of the camera is entirely misleading, since the liquid in the level and the position of the bubble are equally subject to the action of the

FIG. 4.

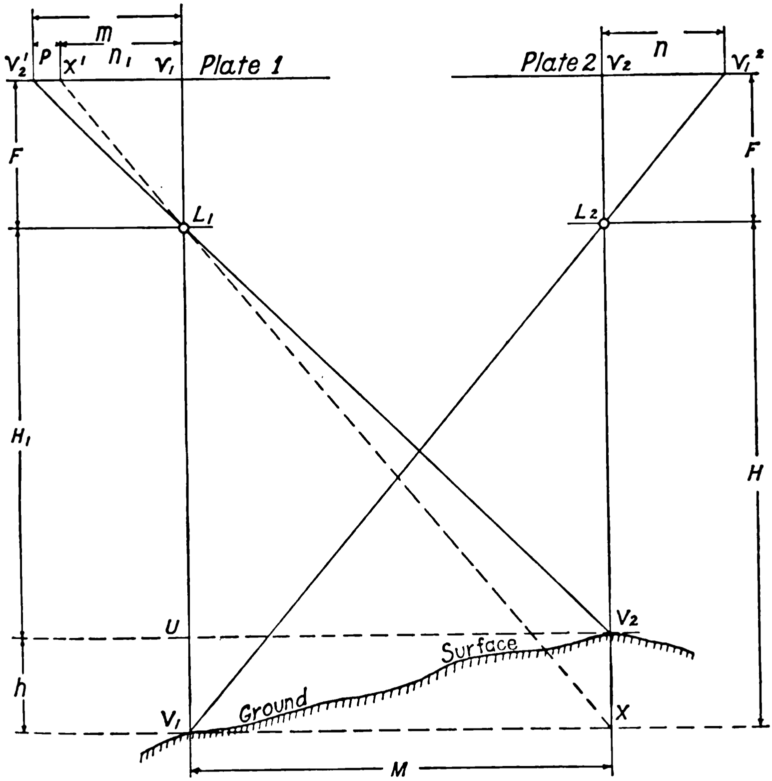


disturbing forces as the camera itself—especially the effect of centrifugal forces by which the direction of the gravitational pull suffers deviation from the vertical, leads to erroneous conclusions. In case a constant centrifugal effect is operative during an exposure period, the camera swings out and the bubble will assume the same relative position as for true horizontality. An actually tilted view would thus be marked as if it were on a horizontal plane. Consequently, such indications are of no dependable practical value.

If, however, the interval between succeeding exposures be so regulated in relation to the angle of view of the lens and of its elevation above the ground, that so much of the image on the first plate of a pair is repeated on the second plate, that the foot point of the vertical through the lens in the first position is still included in the succeeding view (with the necessary corollary that the first image will include the foot-point of the lens perpendicular of the second view) the section of the country between these perpendiculars will occur

in both views so as to create a stereoscopic pair—and it will be shown that it is possible to predetermine the relative position of corresponding stereoscopic points on the two plates, without determining the absolute position of those points on either plate individually. Moreover, to determine such rela-

FIG. 5.



tive positions only the difference in the elevation of the corresponding ground points need be known. The field work is thus reduced to gathering a series of level determinations, without need of any data for the relative location of such points. The consequent reduction in the required field work is of the utmost importance for the commercial aspects of the method.

For the sake of completeness, be it here stated, that besides

the lines of level observations to be made in the field, it is necessary to obtain at convenient intervals, which are always large, a few actually measured distances between two ground points, of known elevation, to serve for the determination of the lens elevation above these base points, and also to determine the resulting scale of the view in that particular plane. Such base measurements are made at ten, fifteen or even twenty mile intervals, between readily accessible points, and serve also to establish and to check the maintenance of the scale in which the aggregate area of the views is combined to one map, all of which will later receive further attention.

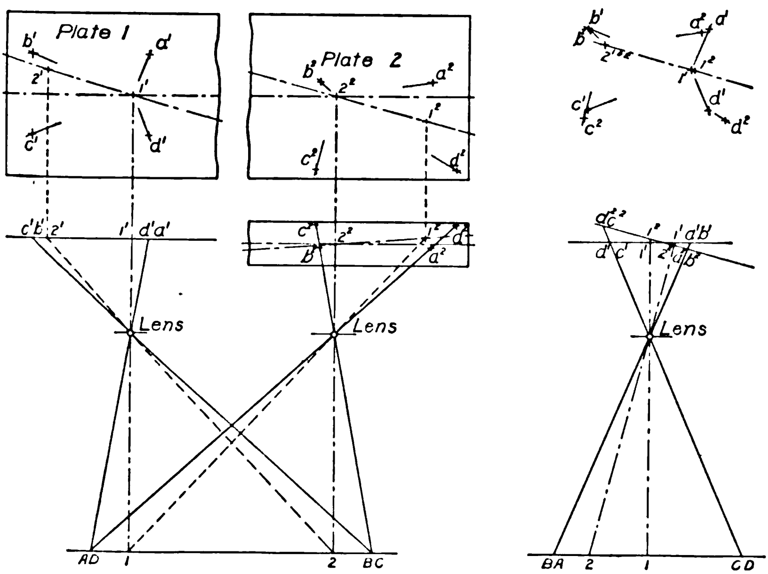
Figure 5 illustrates the compulsory relative location of what are known as conjugate image points; that are the two points which depict the same ground point on adjoining views. It will be noted that two ground points in the same elevation will be projected in both views at exactly the same distance apart, although they may appear in entirely different positions within the physical limits of the views. Other points, situated in different ground planes, will be projected at unequal distances on both views, points. This *difference* is a function of the distance between the views, the elevation of the lens above the ground and the elevation difference between the ground points, but their own actual horizontal distance is of no effect on this function, which by plain geometry can be proven to be: $M \times \frac{F}{H} \times \frac{h}{H \cdot h}$, when F, M, H and h are respectively the symbols for the focal length of the camera lens, the base distance intervening between the two views, the lens elevation above a chosen reference plane and the height of the ground above that plane. The value h is intrinsically positive and becomes negative when referring to points below the reference plane. In each particular case the value $\frac{MF}{H}$ represents the scale of the photograph and can be measured on the view. Using the symbol $\cdots b$ for the image of M, the above equation takes the form $\frac{bh}{H - h}$ or $b \times \frac{h}{H - h}$, from which it will be at once noted that for any given pair of views h is the only variable, and that for stated values of

the fraction $\dfrac{b \times h}{H - h}$, i.e. for a given amount of parallax difference, the corresponding value of h is determined.

We can thus now stipulate that the meaning of the word "parallax" as applied to vertical aërial views is the difference in distance between two pairs of conjugate image points due to the difference in elevation of the two corresponding ground points. After this we can continue to study the manner in which this phenomenon may be used to determine the position of the image planes of arëial views at the instant of their exposure.

In the actual practice of photography from aëroplanes, the image planes are not horizontal, but something on the order of what is shown by Fig. 6 will occur. So as not to

FIG. 6.



unnecessarily complicate the problem, only the right-hand view has been shown as tilted, to illustrate how the distance between image points in a tilted plane become different from what they are on the corresponding horizontal plane, which is shown in dotted lines. Let it be assumed that a pair of

views were exposed as here illustrated, and that the relative elevations of ground points A, H, D and G have been ascertained in the field. H and D are in the same elevation and the distance HD has been measured to furnish data for the lens elevation HO above the plane HD, which is then $\frac{HD}{h^1d^1} \times F$.

Since the amount of tilt is as yet unknown, it is assumed that the distance between the center point $C1$ of the left-hand plate and the conjugate C^12 of the center point $C2$ of the right-hand plate is the actual distance between the two view points O_1 and O_2. Having ascertained by measurement in the field what the relative elevations of the ground points A, H, D and G are, it can now, with the aid of the parallax equation be determined what, the parallax differences between the corresponding image points must be. It will be most easily understood if actual values be assigned, for instance as follows:

Distance measured between H and D	1,345 feet.
Distance measured on the plate between $h1$ and $d1$	1.984½ inches.
Focal length of lens	8½ inches.
Resulting elevation of O above the plane HD	5,735.96 feet.
Distance measured on plate between $c1_1$ and $c1_2$	3.222 inches.
Height of point A above plane HD	44 feet.
Height of point H above plane HD	0 feet.
Height of point D above plane HD	0 feet.
Height of point G above plane HD	21 feet.

Calculated parallax H–A = .0249″.
Calculated parallax H–G = .0116″.
Calculated parallax H–D = 0″.

This pair of plates is now placed on the measuring stereoscope and the parallax differences for these various points are found to be:

$$H\text{–}A = .0269 \text{ error } + .002,$$
$$H\text{–}G = .049.6 \text{ error } - .038,$$
$$H\text{–}D = .008.8 \text{ error } - .008.8,$$

and comparison with the computed values, indicates the errors here shown.

Not only does the presence of these errors indicate that

either one or both of the views are tilted out of horizontality, but their magnitude and sign in conjunction with the location of each of the observed points permit to reach some very valuable conclusions about the magnitude and the direction of the tilt angle in either of the views by the following method of reasoning:

Bearing in mind that the stereoscopic measurements are made on glass positives prepared from the original camera negatives, and that the observer's eyes occupy positions comparable to those held by the lens, so that we are looking down from the viewpoint of the exposure toward the earth, the circumstance that the errors noted in the locations of points *D* and *G* are negative is indicative of the fact that these points are too near the center of plate No. 1, while the small positive error in point *A* is indicative that $a1$ is too far away from that center. We further note that the conjugate point a^2 on plate No. 2 is quite near to the margin of this plate and that consequently the right-hand view has been very nearly level, as otherwise the point $a2$ would have been displaced enough to create a far greater error in the measurement $a1$–$a2$ than was observed.

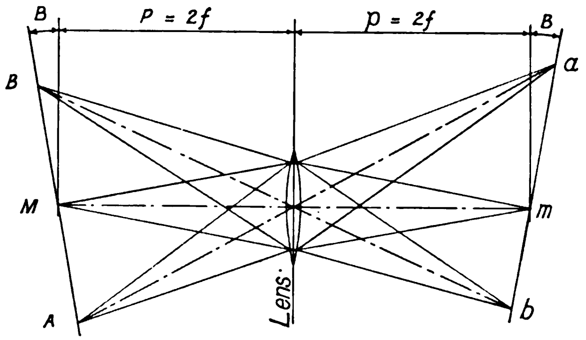
Relative to $g1$ and $g2$ these conditions are just reversed. In this case an error of considerable magnitude exists and since $g2$ is not far from the vertical axis passing through $C2$, the point $g2$ could only have suffered slight displacement as a result of the tilting of the right-hand plate, and it is thus fully warranted to attribute the discrepancy in the measurement of the distance $g1$ $g2$ mainly to the tilt existing in the left-hand plate. Such tilt must have been in the direction which brought the point $g1$ too near to the apex of the light cone, that is the portion of the left-hand plate on which $g1$ occurs was too near the lens, and the plate was tilted *in* on its right-hand side.

An examination of the error in the distance $d1$ and $d2$, which is smaller but of the same sign as the error noted in $g1$, tends to confirm the conclusion just made. Furthermore, the locations of the points $g1$ and $d1$, relative to the vertical axis passing through $c1$, are quite compatible with the relative magnitude of the errors observed in these points. This leads to the conclusion that the errors are probably due to inward

tilt of plate one around the line passing through $c1$ at right angles to the common center line $C1\ C2$ without additional tilt around the latter line.

The negatives of plates 1 and 2 are now inserted in the correcting projector and plate No. 1 is adjusted so as to bring the estimated tilt axis in coincidence with the tilt axis of the

Fig. 7.



projector, and its focal plane inclined to the angle corresponding to the estimated tilt angle, leaving for the time being the focal planes of the projector containing the right-hand negative at right angles to their lens axis.

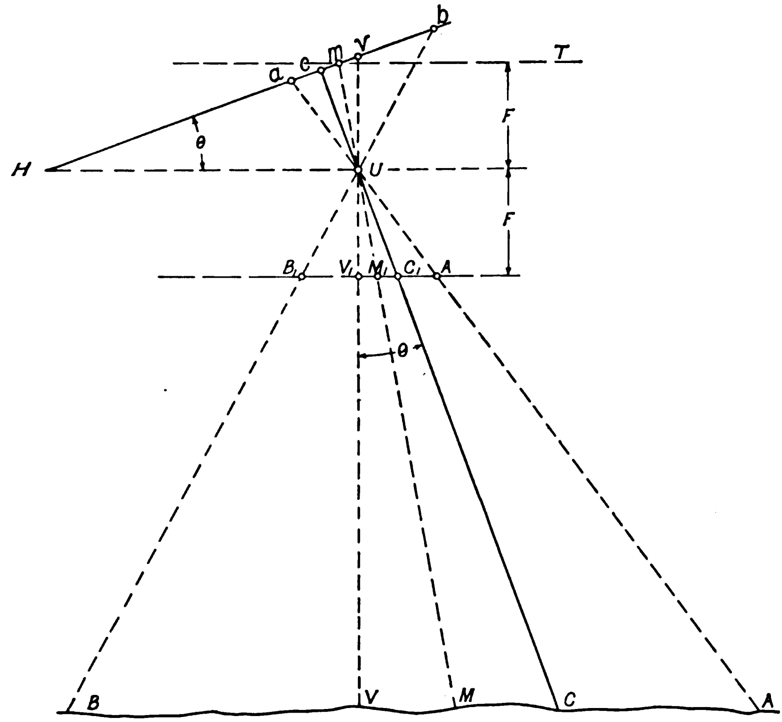
CORRECTING PROJECTOR.

The angular adjustment given to the left-hand negative has been automatically accompanied by the corresponding angular adjustment of the image receiving screen in the positive focal plane, and further by such decentration of the negative and of the screen as is necessary for the former to insure freedom of distortion and for the latter to indicate the vertical point in the image projected on it. This permits to determine the exact effect of the changes resulting from the tilted projection. With the aid of Fig. 4, the necessity for these adjustments will be made clear.

The inclined plane *Ha.C.* contains the tilted negative *a.C.* produced with a lens *f* of the focal length *Uc*. The horizontal plane *HU* through the optical center of the lens is the horizon plane of the tilted image, and the point *H* is the vanishing point for parallel horizontal lines. The dotted hori-

zontal plane B_1A, at the distance f below the viewpoint U, contains the correct positive image and corresponds not only to the tilted image plane $a.b$, but also to the ideal negative

FIG. 8.



plane mT at a distance UV equal to f above the viewpoint U. This ideal image plane intersects the tilted image plane in a line passing through the point m, which line and point are thus common to both planes. Consequently, various image points found in this line have suffered no mutual displacements by being projected on the tilted plane. The point m lies of necessity in the bisector of the tilt angle θ, from which it will be noted that the triangle HUm is isosceles, since the angles HmU and HUm are equal by construction, viz: $\frac{180^\circ - \theta}{2}$ or $90^\circ - \frac{\theta}{2}$. If, then, the broken line CUM_1 be replaced by a straight optical axis in the direction M_1Um

and a lens having a focal length $\frac{UM_1}{2}$ be substituted in U for the actual camera lens, it will be clear that with suitable illumination of the negative in the tilted plane ab this lens will create the correct image AB_1, its horizontal equivalent, and of the same size as would have been produced from the ideal negative plane mT with a lens of a focal length of $\frac{f}{2}$.

In practice, however, it is not feasible to proceed in this manner, as every different negative tilt would require a different focal length for the corrected reproduction. Mathematically correct horizontal equivalents can, however, be produced with lenses of almost any arbitrary focal length, so long as a few very simple conditions are complied with.

To horizontalize any view it is, of course, first of all essential to remove the vanishing point H to infinity. A projector with inclined focal planes accomplishes this for that point in the negative plane which coincides with the intersection of a plane drawn through the optical center of the lens parallel to the directions of the positive focal plane. No other point will comply with this condition, as will readily be seen from an inspection of Fig. 7, which diagrammatically illustrates the condition for the maintenance of conjugation between tilted planes. The points m and M in the optical axis of the lens are conjugate points so that the distance $Ob = (n + 1)F$, and $Oa = \frac{(n + 1)}{n} F$, when F is the focal length of the projector lens and n the ratio of magnification in the lens axis. If, now, these points m and M are considered to be pivot points for the planes $a.C.$ and AB, which have a common intersection T in a plane UT normal to the lens axis in the optical center U, the two inclined planes will be conjugate over the entire range of the field of the lens, without any demand on its quality of depth of focus, as may be readily proved by applying the law of conjugate foci to these planes. The same condition is more conveniently expressed by the equation: $tg\,\beta = n.tg.\,\alpha$, in which n is the relation $\frac{UM}{Um}$ that is the ratio of reproduction in the lens axis. If, now,

the image field in the plane ab be thought sufficiently extended to include the point H produced by a plane UH parallel to $AB.$, it will be evident that the image of the point H will be rejected to infinity in the plane AB. It can further be shown that a perpendicular to the line Mm through the point H cuts the distance Um in two parts—Lm and UL, of which OL represents the focal length of the lens F placed in O. By construction the angle UHL is angle β and hence $F = HU \sin \beta$ or $HU = \dfrac{F}{\sin B}$.

It will also be noted from Fig. 8 that in the tilted original, the distance HU of the vanishing point to the lens is equal to $\dfrac{f}{\sin \theta}$ and since HU in the negative must equal HU in the projector, we find $\dfrac{F}{\sin \beta}$ must equal $\dfrac{f}{\sin \theta}$ or $\sin \beta = \dfrac{F}{f} \sin \theta$. Since for any given camera and projector the values f and F are constant there exists thus the simple relation $\sin \beta = R \sin \theta$ when R equals $\dfrac{F}{f}$.

We have already found that the distances HU and Hm in the negative are equal, and consequently we will know that the point H of the tilted negative coincides with the point H of the projector, when the point m is placed in coincidence with the intersection of the arc drawn with the radius HU and the negative plane $a.b$. The image of the point m will then be projected on the plane AB in the point M and the relative scale of its reproduction will be the same as if m and M had been projected on parallel planes at right angles to the lens axis through each of these points. Since the scale in the m line of the tilted negative is, as already stated the same as the scale in the m line of the ideal negative, this will also be the true scale relation between the corrected projected image and the ideal original. However, this scale is as yet unknown, and since we must arrive at recognition of the corrected image by comparison of parallax values, it is essential for our purpose that the scale in the m line be known. This can most readily be accomplished by so arranging the angles α and β that the m point will coincide with the lens

axis. A further inspection of the Fig. No. 7 shows that the arc already mentioned intersects the lens axis in a point distant $2F$ from the lens U. The law of conjugation requires, then, that also the point M must be at a distance $2F$ from U so that $\frac{(n-1)}{n}F$ equals $(n+1)F$. This equality is only obtainable for the value $n = 1$ and consequently in that case $tg\beta = tg\alpha$ and both $\sin\beta$ and $\sin\alpha$ are then necessarily $= R\sin\theta$. We then arrive at the positions illustrated in the Fig. 7, in which the points m and A coincide and consequently also M and B and which yields a reproduction which constitutes the equal sized horizontal equivalent of the ideal image plane mT.

Coincidence of the point m with the lens axis requires that the optical center of the negative C_1 be decentered toward T by the amount: $f\tan\frac{\theta}{2}$. When this point is set off on the line, Hm and a line drawn through U and C_1 is produced until it meets the plane MT, the intersection locates the center C on the corrected image. If, now, the screen upon which this image is received be decentered from its normal position also through a distance $f\tan\theta_2$, the screen point which originally was in coincidence with the lens axis will then indicate the true location of the v point on the corrected projected image. This allows to ascertain the distance $V_1C_2^1$ on this image, which for the given adjustment represents the true picture base intervening between the two projected views. With this information the lens elevation E can be recomputed and consequently new values for the parallax differences between the points A, H and G can be established and measurements of these parallaxes on the two projected images compared thereto.

Assuming that the focal length of the projector lenses is $9\frac{1}{2}$ inches, the angle β would in the present example have been adjusted so that $\sin\beta - \frac{9.5}{8.5} \times \sin 1^\circ\ 30' - 1.1177 \times .026177$ $= .029258$ or $\beta - 1^\circ\ 40', 35'\ 69''$ and inversely when an adjustment of β to this angle is found to produce an image indicating the correct parallax differences, the tilt angle is derived by the equation $\sin\theta = \frac{\sin\beta}{R}$.

If, upon the first tentative adjustment of the tilt angle β the resulting image does not yet show full compliance with the conditions of horizontality, the changes which have occurred will readily suggest to an experienced operator which additional adjustments will lead to the desired result.

The operations just described could not be carried out successfully without means in the correcting projectors to continuously decenter the view in accordance with the value $ftg\,\frac{\theta}{2}$ for any angle, which according to the relation $\frac{\sin}{R}\sin = O$, corresponds to any tentative angular adjustment of screen and negative. Intricate as this relation may at first glance appear, it is readily complied with by the simple automatic decentration mechanism applied to the correctors.

Having reached adjustments, which produce images that indicate horizontality of the image plane by proper agreement of the parallax differences, the screens are removed and sensitive plates inserted to receive the corresponding exposures, which are then used for the further step required in the actual production of a map. These plates are now ready for the several operations in the fourth group of activities, which deals with the assembling of the separate views to the aggregate of the surveyed area. Much of the work to be done under this heading has progressed alongside of the labors involved in carrying out the process of correcting.

This fourth group comprises everything pertaining to the horizontal control of the map, and insures the proper relative location of the views contained on the various plates and the maintenance of the true uniform scale of the map to be derived from the views.

In the over-great majority of instances, positive prints on glass of the uncorrected camera negatives may be used for this purpose, as in general the tilt in any plate is so small that the resulting directions from certain selected points to the optical center of the plate are practically unaffected. The result of tilt is to displace image points radially in or out, thereby disturbing their mutual distances, but the directions connecting each point with the assumed center of projection are hardly changed. Furthermore, if inadvertently a plate may have been more severely tilted, the resulting

measurable errors in direction become at once manifest and the work of assembling the traverse or plot is halted until the corrected plate can replace the badly tilted one. A further feature, which makes the use of uncorrected originals quite practical for this particular purpose, is found therein that the scale of successive views is absolutely immaterial, as only directions and no actual distances come into play in this branch of the work and the scale of the map is entirely independent from the scale of the negative. In practice the plates are exposed in approximately one-half the scale determined upon for the final map-drawing. This rests, however, on considerations of expediency and economy, as in that manner an enlargement of the original view to two diameters furnishes a plate containing approximately four times the area to the same scale which would result if the photographic flight had taken place at an elevation corresponding to the map scale. Only one-quarter of the number of views is required to cover a given territory and the increased distance between the required control points has been doubled, thereby not only increasing precision but reducing the cost of field operations. Incidentally, the increased point displacements on the enlarged views due to tilt in the original exposure become sufficiently large that deviations from horizontality as small as $0° 2'$ may readily be recognized and corrected.

The enlarged views are sorted in groups of three to roughly blue pencil on the first and the last of each such group the extent of their overlap. Plate one and two of the group are then placed on the measuring stereoscope and a series of suitably located image points within the blue pencilled area are stereoscopically picked out and marked on each of the plates under examination. These points are thus found also on the third plate of this group, so that by stereoscopically examining the second and the third plate, the corresponding conjugate points on the third plate in its blue pencilled region are marked with the aid of the already marked points on the middle plate of the group. Also, wherever they appear, the conjugate image points of the ends of a base-line measured on the ground are similarly marked.

Having in this manner selected a sufficient number of points that occur on three succeeding plates, besides a few

which occur only on two plates, their angular directions relative to the lines uniting the succeeding view-points are transferred to the plot drawing. This drawing contains thus, in pencil, a series of radially extending lines, each one indicating the direction from one of the picked points to the center of the plate—also the direction between this center and the centers of the adjoining plates. These directions are, in fact, the azimuth angles under which the various object points corresponding to the several image points would be observed from a ground point coinciding with the optical center point of the view—and are obviously not affected by the relative altitudes of any of these points. If, then, two adjoining plates are superimposed so that the lines uniting the center points of each view are in actual coincidence, the lines radiating from the center of plate No. 1 will intersect the lines radiating from the conjugate image points to the center of No. 2 and in their intersection determine the correct location in orthogonal projection. Sliding one plate over the other parallel to the direction of the common center lines, the various intersection distances will increase or decrease in direct proportion to the increase or decrease of the distance between the points C_1 and C_2, which permits to regulate the scale at will to any predetermined value.

Referring back to the length of the measured base HD, which was found to be 1345 feet, and adopting a map scale of 600 feet to the inch, the distance HD on the map should be $\frac{1345}{600}$ inch = 2,240″. The plates should then be shifted until the intersection of the rays to the points H and D are exactly that distance apart. In that adjustment the exact intersections of the H and D lines are laid out on the map-sheet, and the points C_1 and C_2 are equally marked. This operation insures the plotted traverse to be in the desired scale. The draftsman now continues to transfer the direction lines toward the various control points, first from one and then from the other of the plates, and when all directions have in that wise been transferred to the plot, draws lines through the points so marked in the direction toward the corresponding centers from which they were marked, thus establishing in the intersection of each pair of direction lines

the true orthogonal location of the corresponding ground point in the correct map-scale.

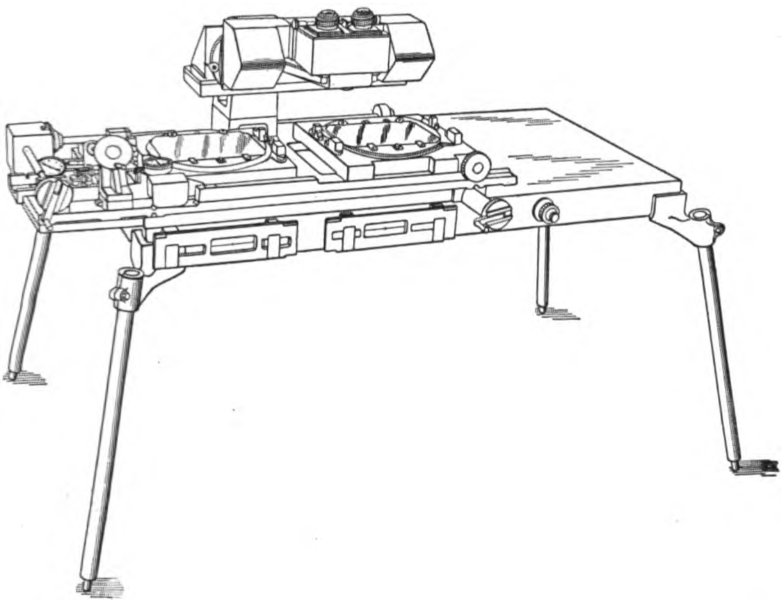
The second plate contains as well the direction line from C_2 to C_3 as from C_2 to C_1—so that when all lines have been drawn, it is now possible to place the third plate so that its direction C_3 to C_2 is in coincidence with the already drawn line C_2C_3. The third plate is then adjusted until the direction marks thereon, to points in the blue-pencilled region, exactly pass through the locations of these points already obtained by the intersections of the first two plates laid down on the plot. It will be readily seen that in this wise a control plot can be built up to extend throughout the area covered by the photographic views. Especially when such areas are so wide that they are built up from a series of parallel strips, the precision obtainable by this procedure becomes very high by the fact that a number of strips may be built up together, giving frequently rise to 5 and 6 intersecting directions to the same point, all of which exactly superimpose themselves. Thereby, the certainty of maintaining correct azimuth directions, as well as maintaining the scale, is greatly enhanced and in practice it is found that on reaching the plotted position of a second control-base, the end points measure with extreme precision the proper distance apart. Such a check covers all of the intermediate point locations, as in the nature of this work errors are not likely to be compensating.

Before taking up the description of the next steps, it is still to be noted that the construction of the traverse, keeping pace in this manner with the correcting of the several pairs of views, permits also to check the flight elevation at which succeeding views have been exposed. If, among the points plotted, be included the several points of which the difference in ground elevation have been measured in the field, the distance between such points as they should appear on any plate for a given scale can at once be determined, and if necessary, the plate in question can then be enlarged or reduced to actually bring such points to the calculated distance.

We now have reached the interesting part, which deals with the production of the contour lines. Pairs of plates have been corrected so that each plate is the equivalent of a

horizontal view in its own viewpoint. The point *v* previously mentioned and the elevation of each viewpoint of the pair have been ascertained and equalized so that all data are on

FIG. 9.



Comparison stereoscope.

hand to determine for each pair with great precision what the parallax differences must be for points situated at the intervals in which the contours are to appear on the final map. Considering again the pair of plates that have been corrected, and in which the base points *H* and *D* are known to be in the elevation of 35 feet above the datum plane of the map, it follows that the lens was 5734 + 35 feet = 5769 feet above the datum, and consequently the parallax for *H* and *D* must be $2 \times \dfrac{1.845 \times 35}{5769 - 35} = 22.4/1000''$ above zero. If the contour interval is to be 10 feet, the first contour line will show a parallax of $2 \times \dfrac{1.845 \times 10}{5769 - 10} = 6.4/1000$. Assuming the maximum elevation occurring in this pair to be 146 feet, all contour parallaxes from 10 to 140—by steps of 10 feet—are calculated

Fig. 10.

A contoured photographic plate.

and noted in a box provided for that purpose on the plate envelope.

Having properly aligned the plates, the operator brings the image points h^1 and h'' each in exact coincidence with the vertical cross hair of the ocular through which it is seen, and with such separation between the two views sets his micrometer dial to read 22.4. He thereupon reduces the distance between the views until the micrometer reads 6.4 and then begins to look for some place in the view where, with this setting, the cross hairs appear to touch the ground. He has now found a point in the 10 foot contour line, and besides, the physiological effect of the cross hair image suggests to him the location of a horizontal plane cutting the plastic stereoscopic view in the 10 foot plane. He draws the clearly visible contour as far as the view will permit, then shifts the two plates together to bring the end of the line he has just drawn to the cross hairs, checks this line by noting that they have kept in contact with the ground all along the line so drawn, and then continues the line for the next visible stretch. Having traversed in this manner the whole image, and having seen its general appearance, he knows where other places in the view present the same contour, and then continues to draw all he finds within the plate area in this elevation. Should he find the contour to be closed within this area, he proceeds to readjust the plate distance to conformity with the next contour line, which of necessity will also close in upon itself within the area of the one first drawn, and continues until the highest contour is drawn. He then proceeds to draw the 20 foot contour line adjacent to the other 10 foot lines already drawn, and so proceeds to draw one by one all the contours appearing within the stereoscopic area of the views.

With a little training an operator gifted with fair stereoscopic perception can in this way draw contour lines with ease and precision following the minutest indentations, every suggestion of drainage and any and all deflections as they occur in nature, be they high up in the mountains or deep down in the valleys, without moving from his stool behind the instrument, enjoying meanwhile the fascination of the richest detailed bird's-eye view. The work is much facilitated

by the fact that the height dimensions are invariably to a much larger apparent scale than the horizontal dimensions, thereby accentuating elevation differences in the view. This

Fig. 11.

Map of Vecchiano and surroundings, Italy.

phenomenon is due to the favorable ratio which exists between the lens-elevation and the picture distance in comparison with the horizontal scale between the picture base and the pupillary base. It differs, therefore, slightly for different operators, but on an average the scale ratio is about as 1 to

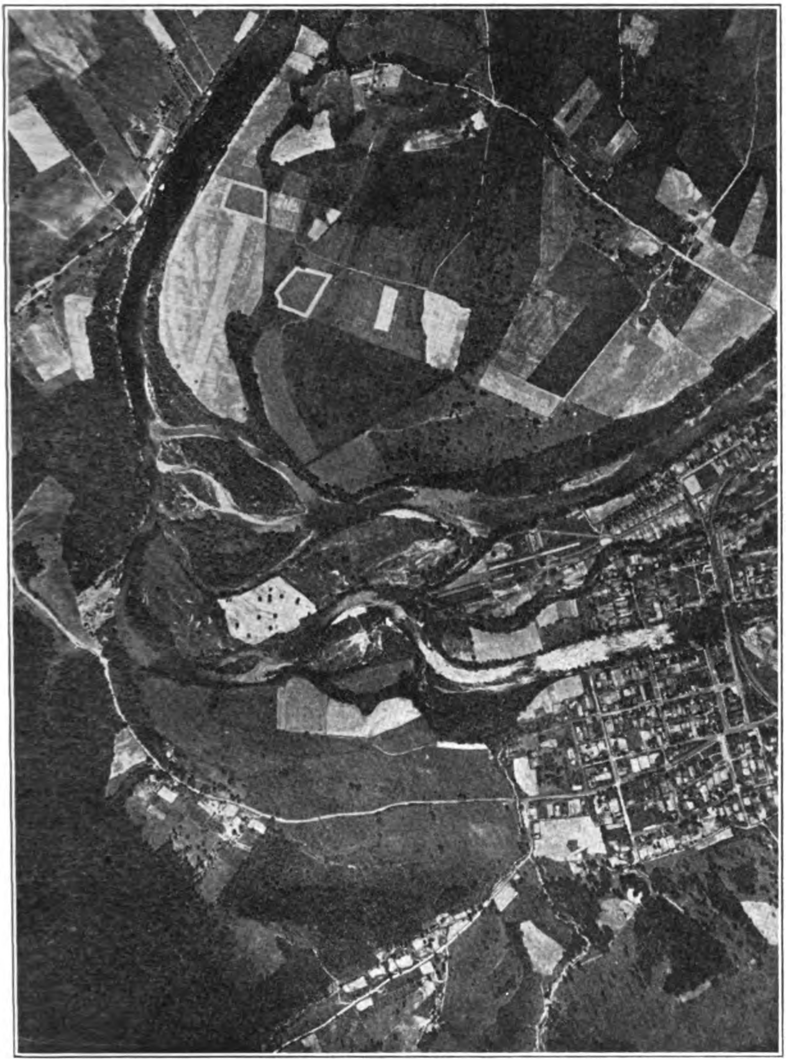
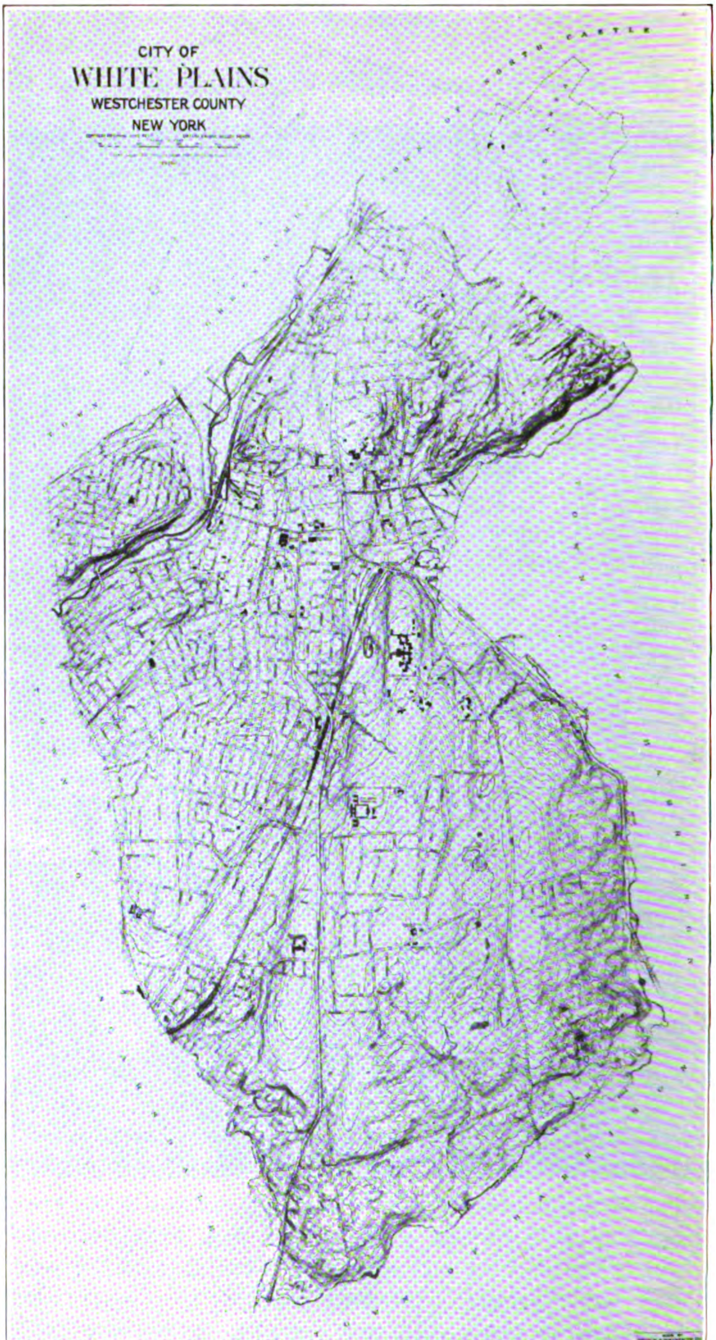


FIG. 12.

Aerial photograph showing the rich detail with which all features of land and culture are reproduced.

FIG. 13.



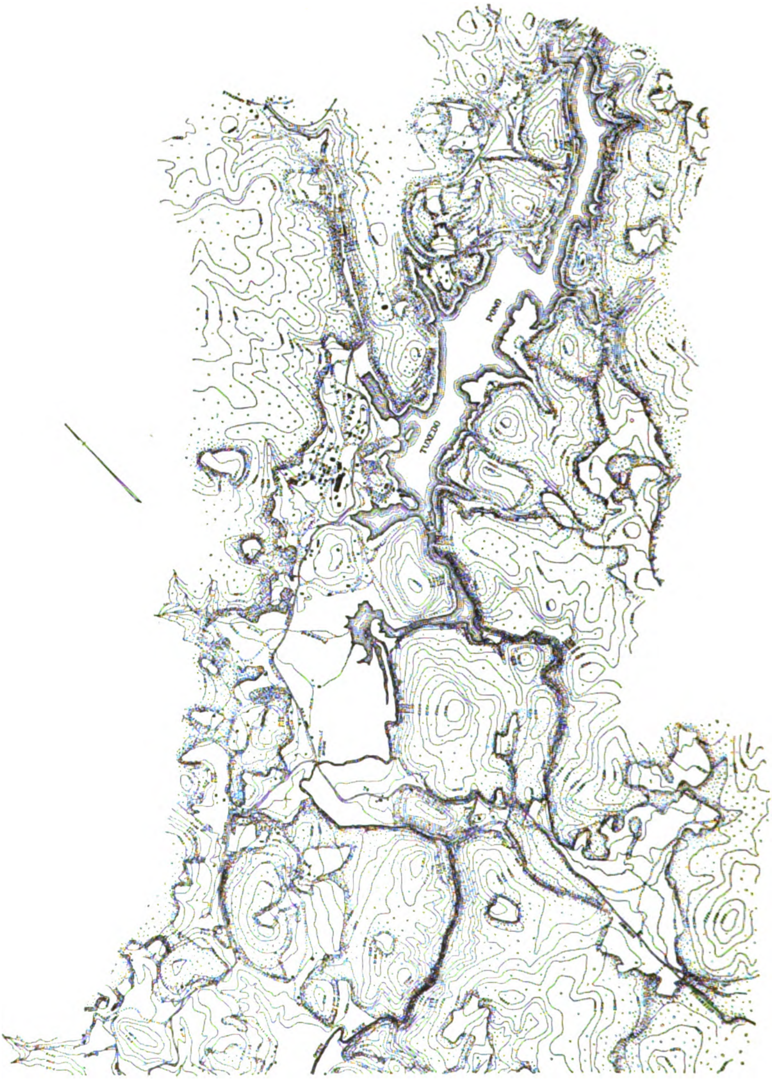
2.8 in favor of the vertical scale. As this effect is purely psychological, the parallax measurements are in no wise affected by it; it just assists the operator in doing this part of the work. It is evident that contour lines so obtained will automatically assume the upwardly increasing scale of the conical perspective of the view, and are thus not as yet ready for transfer to the plot.

The sixth group of method steps concerns itself with the conversion of the conical or central projection of the views to the orthogonal projection of a map.

This difference is perhaps most readily grasped by comparing photographs and maps respectively with the architect's perspectives and his working drawings. The first show things as they appear, the latter as they actually are. The difference is brought about by removing the center of projection to infinity and therewith removing all perspective from the original views. Up to this point, the presence of perspective was the very thing which permitted to carry out the necessary successive steps, but we have arrived at the proper time for eliminating it, in order to convert the drawings to true uniformly scaled sections of the map under construction. It should be kept in mind that, strictly speaking, the previously described construction of the map-traverse, the actual framework upon which the map is gradually drawn and completed, is the first of the operations for the elimination of perspective, and it appears that at this moment a comparison of the method described with those in Europe will be best understood and appreciated.

Independent from any method whatsoever to determine the actual plane of projection, European constructors have all designed some pantographic machinery, which is used to directly convert the uncorrected view to the corresponding map drawing. They deserve high praise for the ingenuity and perfection of workmanship developed in this respect, but their practice suffers from the circumstance that they can never add more than one view at a time to those previously located, as the very result of their practice of building the pantograph systems in unison with the stereoscopes and operating them by causing the stereoscopic views to pass underneath the comparator marks of the stereoscopes.

Fig. 14.



Early example of aerial photography.

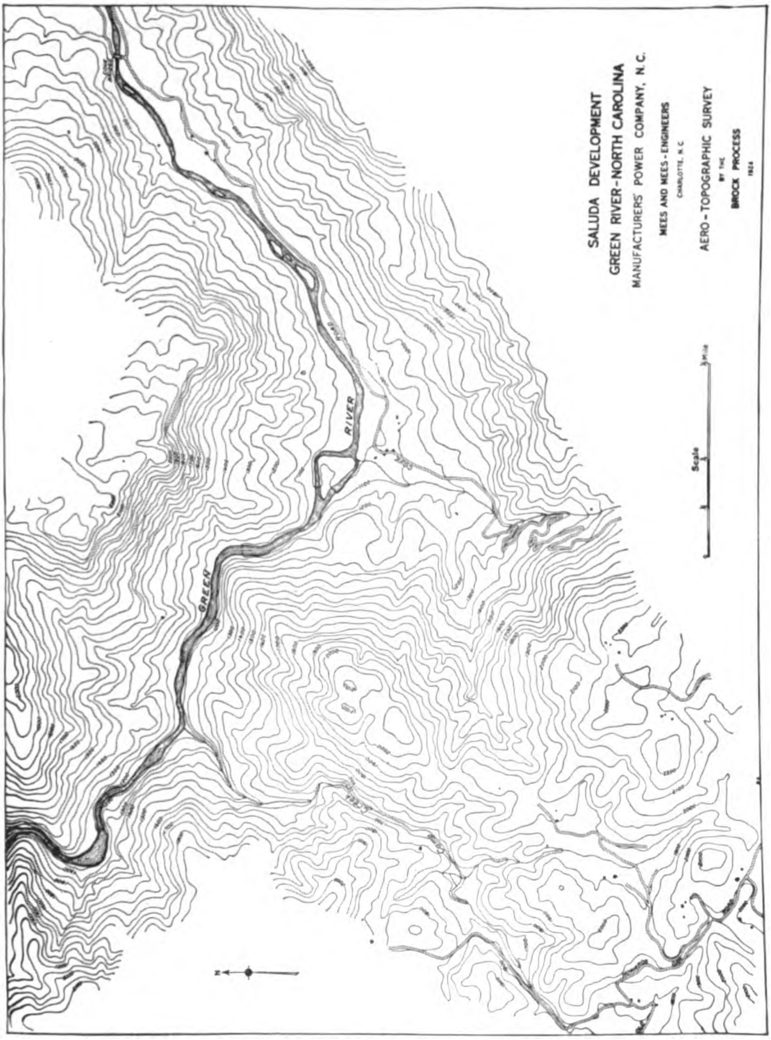
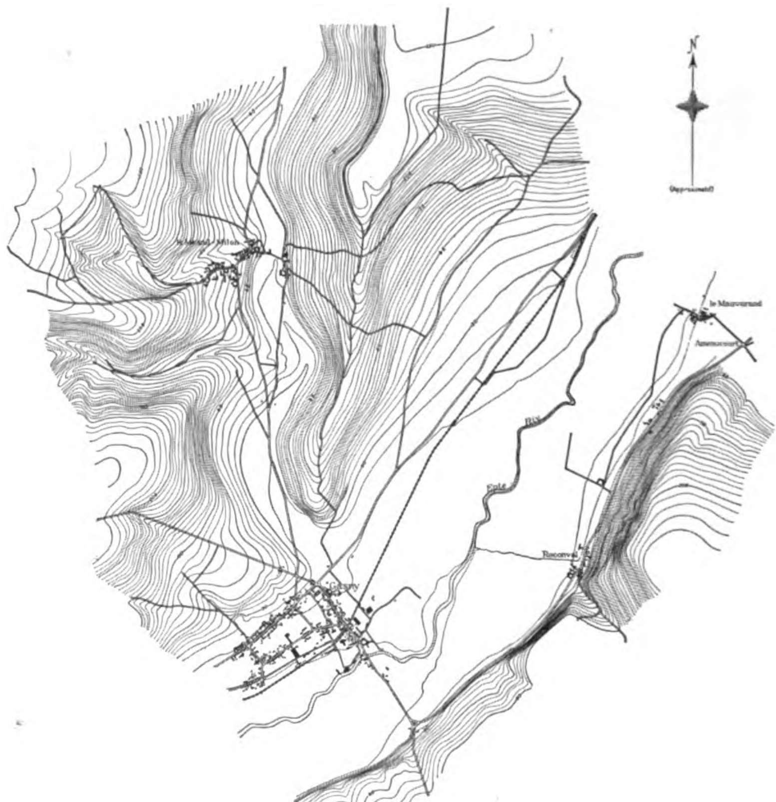

SALUDA DEVELOPMENT
GREEN RIVER-NORTH CAROLINA
MANUFACTURERS' POWER COMPANY, N.C.
MEES AND MEES-ENGINEERS
AERO-TOPOGRAPHIC SURVEY
BY THE
BROCK PROCESS
Scale
GREEN
RIVER

FIG. 15.

In adjusting a pair of plates to their stereoscopes, they arrive at certain settings and must then adjust the previously produced part of the pantographically drawn map to perfect orientation with the new pair of plates, the contents whereof are to be added to the drawing.

In the case of the method here described to the contrary, as well during the building up of the traverse as during the

Fig. 16.

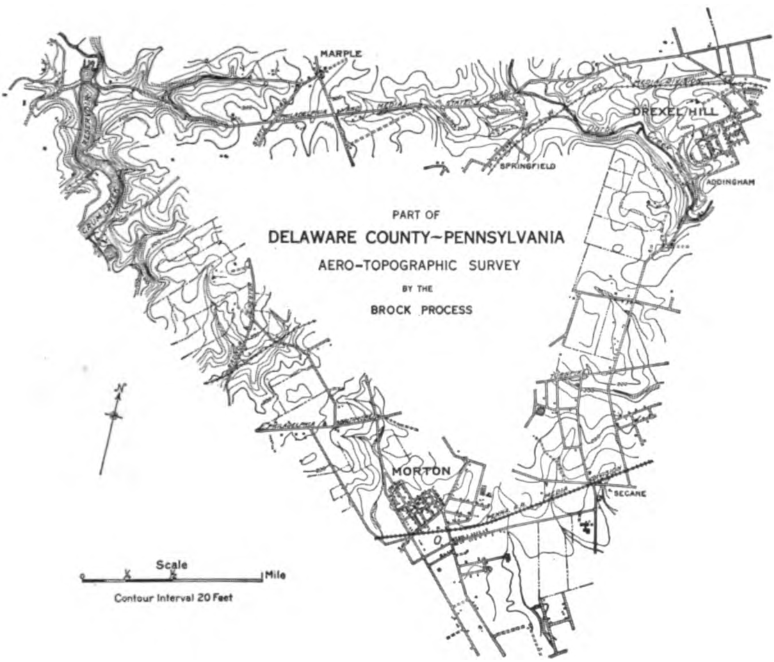


Map of the surroundings of Gasny, France.

transfer thereto of the various map-sections, there are provisionally assembled as many as ten or more sections simultaneously, and thereby a precision in orientation is secured,

unattainable by the European method of procedure.—The ability to produce continuous differential scale equalization is emphasized, whereas in the described method this equalization occurs only zone fashion. Here is, however, a truly and exclusively theoretical point of no practical value, as the very valuable advantage of the high precision in orientation resulting from the American way of proceeding more than offsets the infinitesimally small difference between zonal and con-

FIG. 17.



The first actual areal test-map.

tinuous scale equalization. It furthermore offers the possibility of letting several draftsmen simultaneously work on adjoining sections of the traverse, whereas the pantograph method makes the final map combining essentially a one-man job. This latter point, though being exclusively a commercial consideration, is nevertheless, or rather therefore, a notable advantage of the American method of working.

In this review of the two methods I have assumed that

pantographs operate with 100 per cent. precision. Granted that this may be so as long as they are new and all adjustments have been made with adequate precision, mechanism as intricate and delicate as it must be to avoid mass-reactions, which interfere with free movement, will not for long remain in such perfect mechanical condition that the accumulated back-lash in the screws, gears, sliding members and pivots does not aggregate to more serious displacements of the pencil point than the possible gain of differential scale variation could possibly secure.

Having said this much in defense of the American method of scale equalisation, its actual achievement is best shown by the profiles here shown which represent a check between a map and the ground, for contour intervals of one foot.

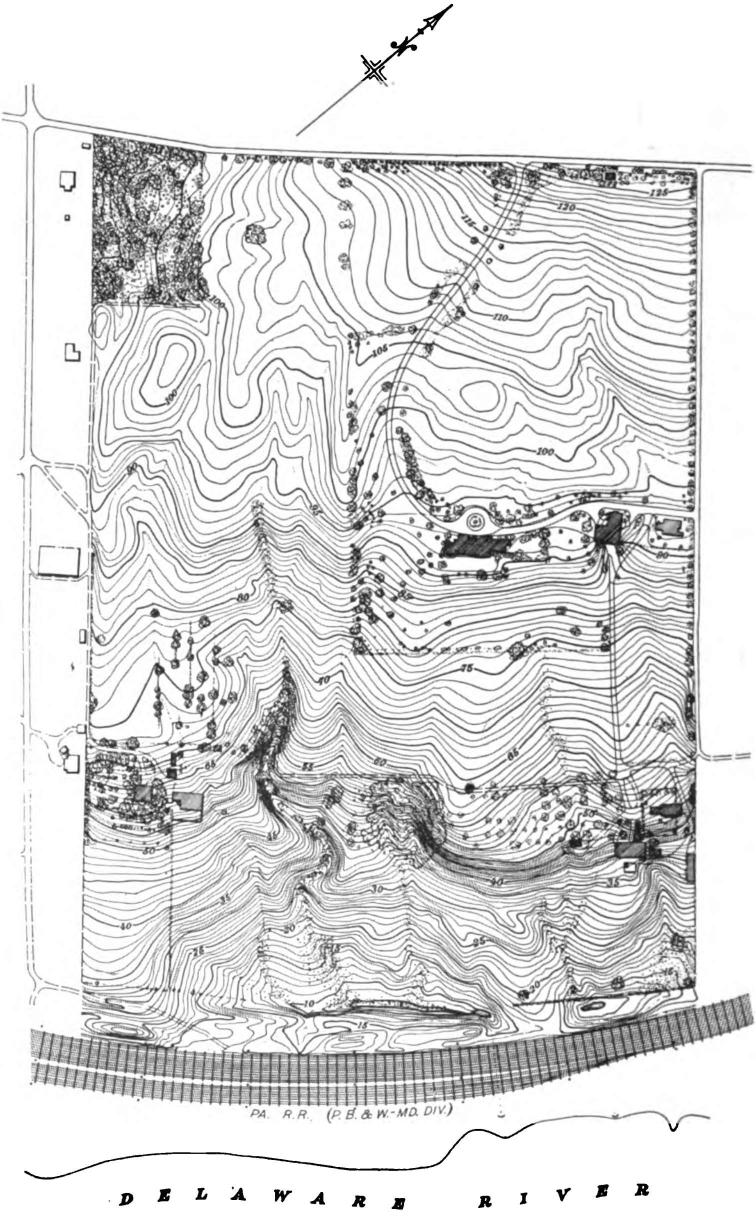
The contour drawing, containing besides the contours as many of the cultural features as are desired to be shown on the final map, is inserted in the camera-end of the equalising projector, which is provided with an automatic focusing mechanism of adequate range on either side of equal-sized reproduction. It projects its image—always on the top surface of the plate glass disk, sunk flush with the top surface of the surrounding table. A sheet of tracing cloth or tracing paper laid flat on this plate glass sheet renders the image visible to the draftsman. The sheet so used has previously been laid over the traverse plot in the region covered by the inserted view so that the true location of the several plotted points of this region are on this tracing when it is first laid on the glass top of the transfer projector.

The size of the projected image is then adjusted so that those of the corresponding points which are included in the inserted contour drawing and happen to lie in the same elevation exactly coincide with the location of the plotted points marked on the tracing. This assures the correct adjustment of the tracing over the projected image, and the magnification is then re-adjusted to the already computed value, which will bring the lowest contour line to the datum plane scale of the map. This contour and the other desired features are thereupon traced, care being taken to continue the roads, rivers and other features not further than half-way to the next adjoining contour line. When this is finished

Fig. 18.

Mosaic showing under water areas.

Fig. 19.



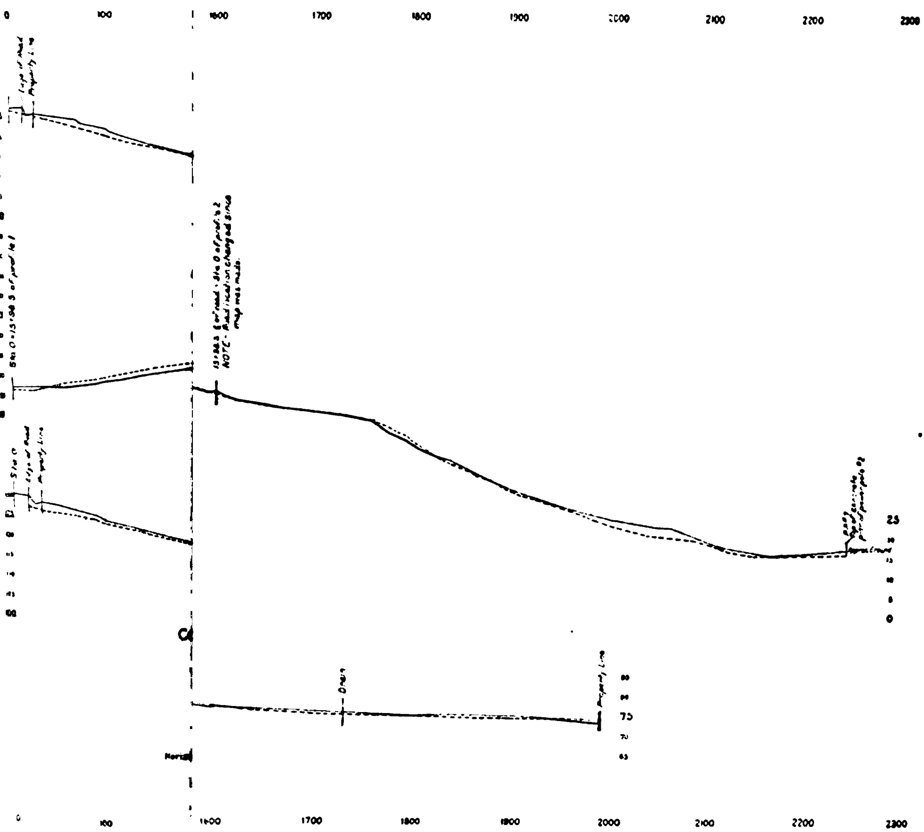
Map showing 1 ft. contours which are checked by the profiles shown on one of the other illustrations.

the image size is re-adjusted to bring the next contour line to the standard scale and the work repeated as before, until the highest contour has in this manner been reduced to its proper scale. The resulting tracing is then a true uniform scale map of the section contained on the contour drawing. The vertical position of this contour sheet in the camera, together with a ventilated lamphouse through which a current of fresh air is forced, allows to let the original remain for the required time without heating it up and destroying its original dimensions within measurable limits. As soon as in this manner a sufficient number of contour sheets has been corrected to drawings of uniform map scale, they are assembled over the original traverse drawing by again registering each one by means of the originally copied plotted points, to examine the exactness of the joints produced by the several sectional sheets among themselves. This never fails to be of remarkable precision, and thereby constitutes a further check on the precision of every preceding step of the process. With suitable weights the several sheets so combined are anchored in position and all but the undermost one are turned back. A sheet of carbon paper of suitable color is laid between this sheet and the traverse drawing, red being used generally when contours are transferred by following the lines of the sealed drawing with a fine rounded steel point. This brings the contours in red on the traverse drawing. A sheet of blue carbon paper is then used to similarly transfer the streams and lakes, and finally with the aid of black carbon paper the various cultural features are transferred. Each sectional drawing being similarly dealt with, the final result is a complete drawing of the map on the traverse plan. As this plan was also derived from the features of the aerial photographs, we possess thus now a truly aero-topographical map of the territory in survey.

As engineering maps are usually desired on tracing cloth, and in equal-sized sheets of standard dimensions adopted by the firms for which they have been produced, sheets of the desired size are then traced from this total traverse and the necessary lettering titles, scales and border lines are added to finally produce the finished product ready to be delivered to the client. It is my pleasure to show you still some slides

of some of the finished work produced by the Brock process, one of which, though small, is truly remarkable in that it shows a tract of ground of approximately 88 acres mapped to an original scale of 200 feet per inch with contour intervals of only one foot. I am certain that thus far no other aerial method has succeeded in accomplishing equal results.

Illustrating the wide range of possible adaptation, figure 21 shows a map of 75 square miles to the scale of 1 inch per 1,000 feet in original construction and reduced to $\frac{1}{48000}$ to fit in with the corresponding sheets of the U. S. G. S. maps.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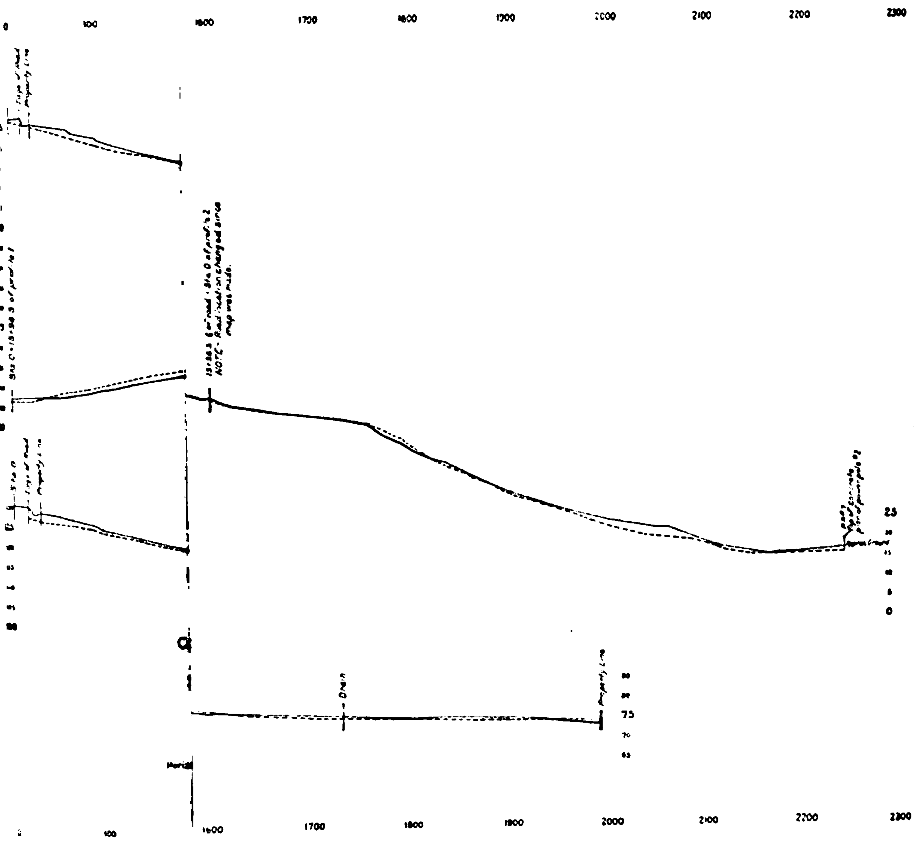
F. I. Oct. 1928

L. J. R. Holst



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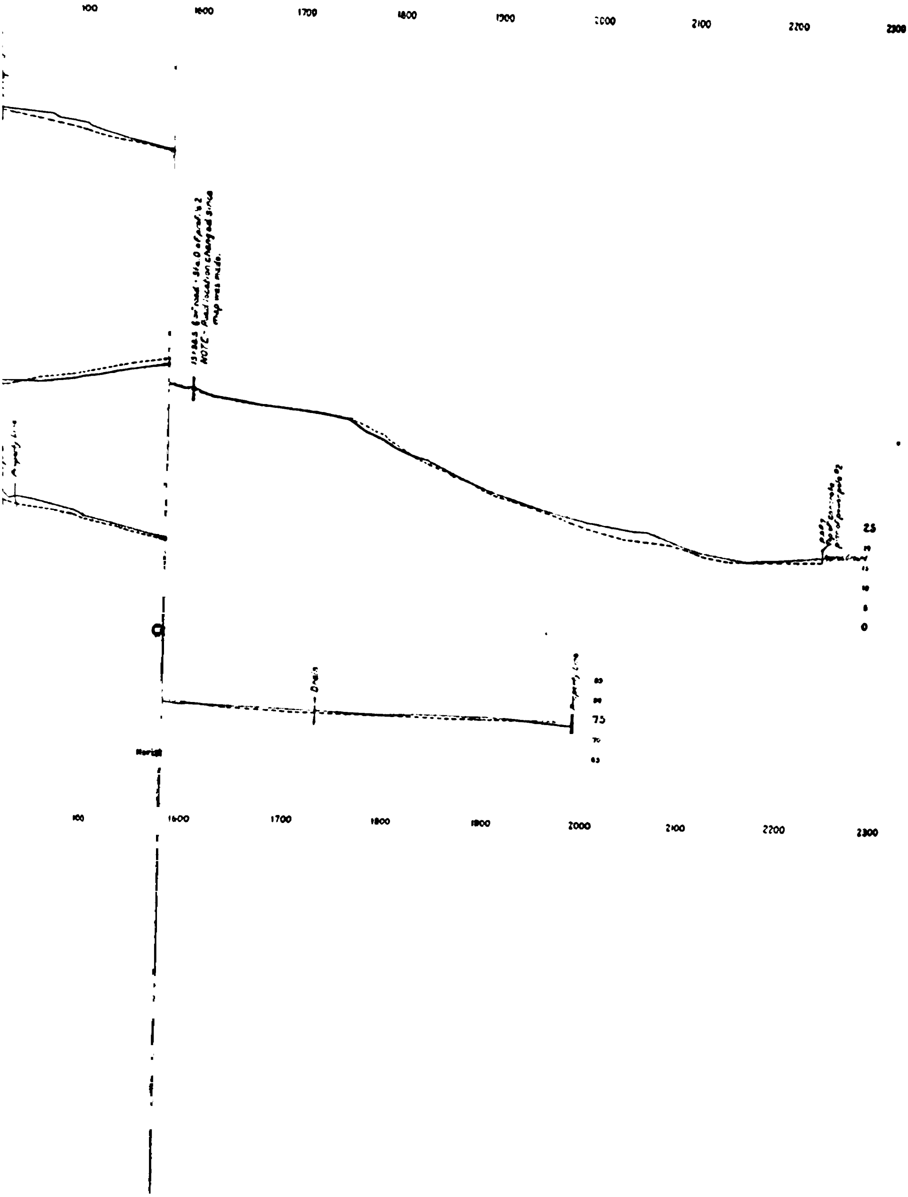
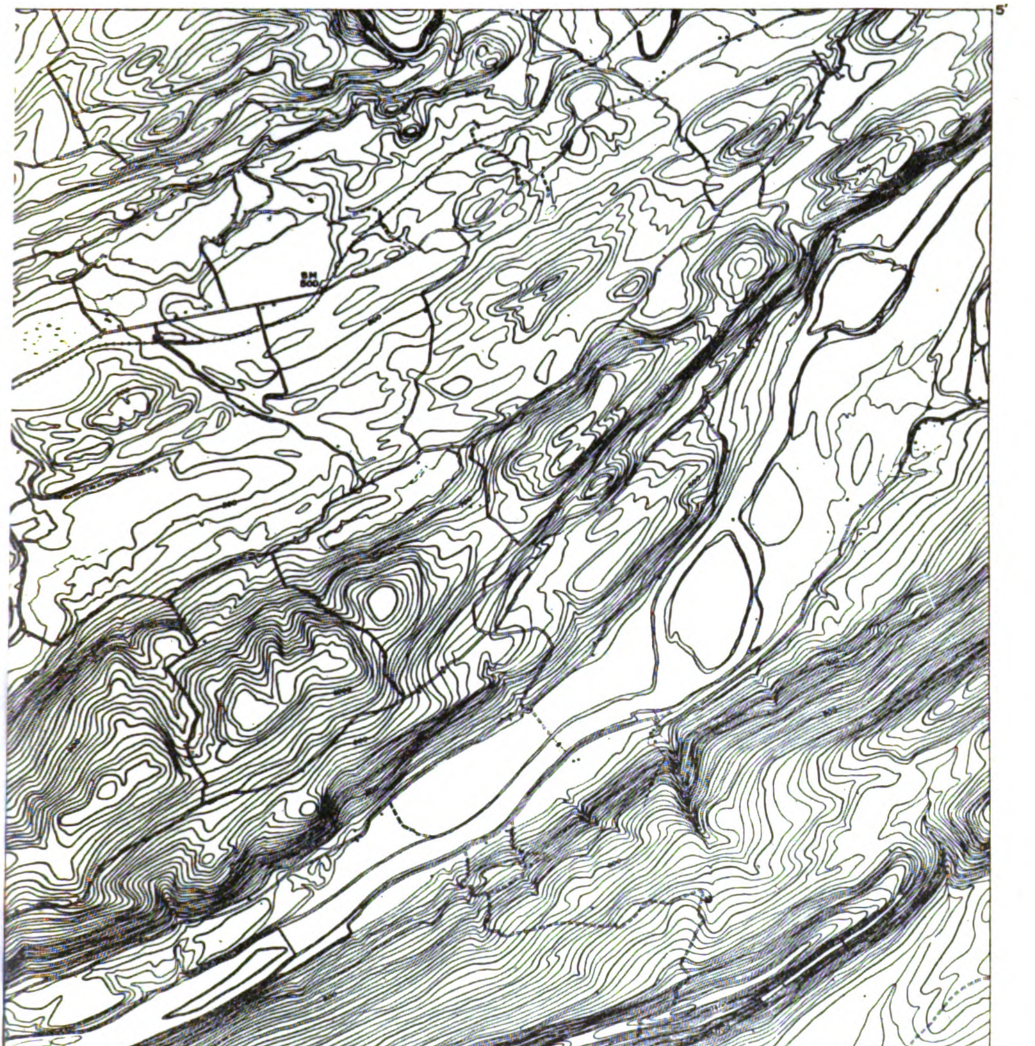
L. J. R. Holst

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ON THE DETERMINATION OF STRESS AND STRAIN DURING IMPACT INDENTATION.*

BY

JUNZO ÔKUBO and MASATAKE HARA.

1. INTRODUCTION.

THE present investigation is an experimental work which was undertaken to ascertain the phenomena relating to the impact of two bodies. A short resumé of the previous investigations[1] will serve as an introduction to this paper.

If two spheres, of the same material and of equal mass, collide with equal velocity, (1) the coefficient of restitution rapidly diminishes as the velocity just before the impact increases, and beyond a certain value of this velocity, it diminishes according to a linear law. (2) The time of contact between the impinging spheres also diminishes as the velocity of the impact increases. (3) The volume of the permanent indentation increases linearly in proportion to the loss of the kinetic energy of the impinging sphere. These results were obtained from the measurement of the velocities of the impinging spheres just before and after the impact, the time of contact and the permanent indentation on the specimen.

Notwithstanding that a complete study of the phenomena of impact is very important not only from purely scientific point of view, but also from the technical application, the experiments hitherto reported have been limited to the measurement of the quantities above mentioned and it is very much to be regretted that few attempts have hitherto been made to investigate the phenomena occurring during the contact of the two bodies. To obtain a precise physical conception of the nature of impact, especially the process by

* From the Laboratory of Physics, Tohoku Imperial University, Sendai, Japan.

[1] J. H. Vincent, *Proc. Camb. Phil. Soc.*, 10 (1898), p. 332; C. V. Raman, *Phys. Rev.*, 12 (1918), p. 442. E. W. Tshudi, *Phys. Rev.*, 18 (1921), p. 423; M. G. Moreau, *Journ. d. Phys. et Radium*, 11 (1921), p. 329; J. Ôkubo, *Sci. Rep., Tohoku Imp. Univ.*, Ser. 1, il (1922), p. 454.

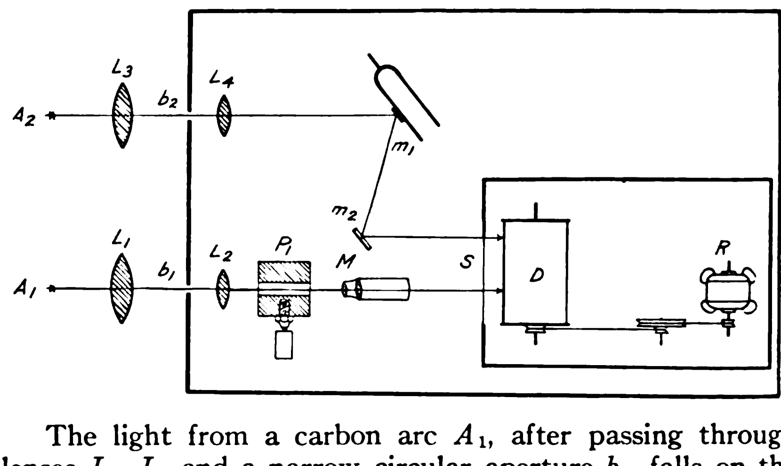
which the permanent indentation is produced, a further experiment will be necessary which will throw light on the mechanical properties of materials beyond the limit of elasticity.

2. EXPERIMENTAL ARRANGEMENT.

It is well known that when a moving sphere impinges on a fixed body, its velocity decreases till it becomes zero, then it reverses its direction, and increases to a certain value. To study the process by which the indentations are produced, it is necessary to obtain the relation between the change of velocity of the impinging sphere and the depth of indentation at every instant of impact.

As the results reported by many authorities show, the duration of the contact of these two bodies is only of an order of 10^{-3} or 10^{-4} seconds, and hence to obtain the record of the motion of the body in this short interval, it is necessary to devise a means by which the whole arrangement shall operate effectively and automatically during the contact. After many unsuccessful trials, we arrived at the following arrangement which worked quite satisfactorily. The plan of the apparatus is shown in Fig. 1.

FIG. 1.

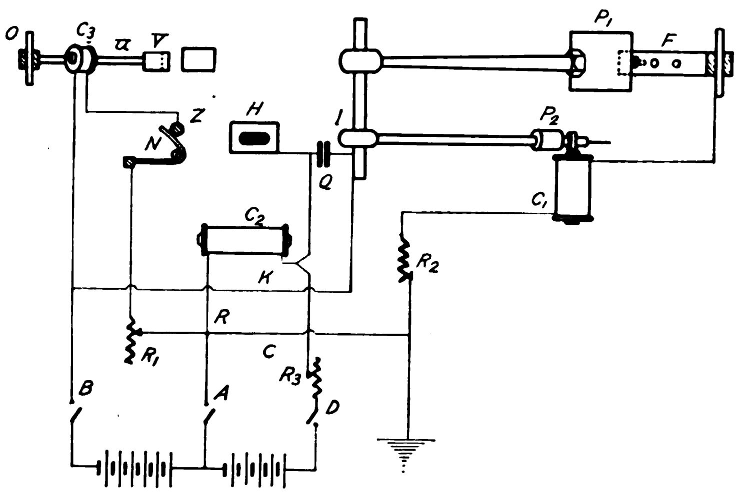


The light from a carbon arc A_1, after passing through lenses L_1, L_2 and a narrow circular aperture b_1, falls on the main pendulum P_1, which carries an impinging sphere made of steel and a small slit measuring 10×0.2 mm., and then

enters the magnifying lens M (the magnifications of this lens being about 18) and a photographic system. Inside the camera, there is a rotating drum D with a photographic film placed at the focus of the lens M, so that the motion of the main pendulum can be recorded on the film. A shutter S of a special device was put between the rotating drum and the magnifying lens and so arranged that it only opened during the period of the contact of the impinging sphere and the specimen. The rotating velocity of the drum can be regulated by a small motor and a system of pulleys of different diameters. At the same time, a beam of light from a carbon arc A_2 after passing through lenses L_3, L_4 and a rectangular aperture b_2, is reflected by small mirrors m_1, and m_2 and register the vibrations of the tuning fork on the same film.

In order that all the parts of the apparatus should operate effectively and automatically for the duration of the experiments, the electrical connection as shown in Fig. 2 was

FIG. 2.



devised. The circuit I ($ARCR_2C_1FP_1KBA$) is closed when the main pendulum P_1 is fastened to a staple F; if this pendulum is set free, the circuit is opened and the auxiliary pendulum P_2, the stem of which is made of brass and the bob of soft iron, moves downwards, and a platinum needle

attached to the end of it, closes the circuit II (AC_2HIKBA), as soon as the needle touches the mercury pool H_1 and the coil C_2 attracts the soft iron tips of the shutter. By the choice of a suitable position for the pool and by using the proper quantity of the mercury, the beginning and the duration of the opening of the shutter can be adjusted, the circuit III (AC_2DA) being used for the adjustment of the current to the shutter. Q is a small capacity. The circuit IV ($ARNC_3BA$) serves for the buffer system which prevents more than one impact of the main pendulum on the specimen.

As the sources of the electrical current, we used secondary batteries of 20 volts and by using suitable resistances R_1, R_2 and R_3 the intensities of the current were regulated. Thus by breaking the contact between the main pendulum and the staple by means of some mechanical device, all the parts of the apparatus operated automatically, and records of the impinging sphere were obtained.

We shall next describe some details of the construction of the main parts of the apparatus.

1. *The Main Pendulum.*—This was made of mild steel, the diameter of the upper and the lower parts of the stem are respectively 15 mm. and 25 mm., the bob B being a circular cylinder having the diameter and the height of 70 mm. respectively. At the center of the bob a rectangular slit S, 10×0.2 mm., was cut, and a hard steel ball T firmly fixed at one side of the bob, the lower end of which carries a small hook h for fastening it to the staple. The diameter of the ball is 6.31 mm., the total weight of the pendulum is 3,128 kg. and its length is 505 mm.

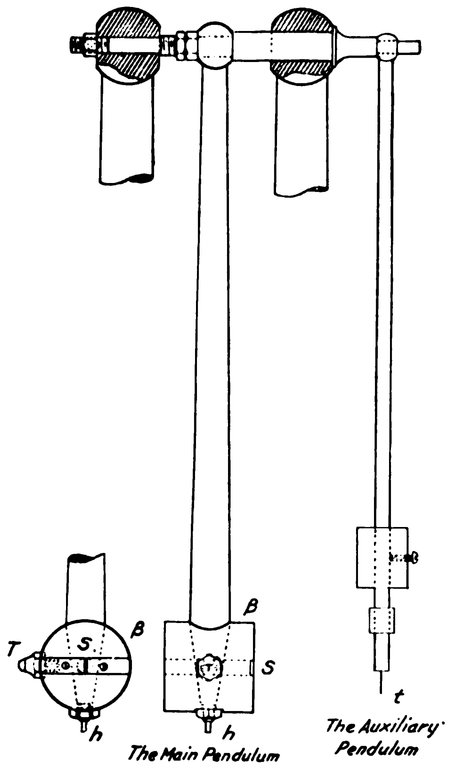
The pendulum could rotate smoothly round an axle and by using a very stout stand for the bearing of this axle, we ensured that there were no flexible and torsional vibrations even when the pendulum impinged on the specimen. To obtain a correct magnitude of the indentation in the steel used as a specimen, we used another pendulum of a similar construction with a stronger stem and a thicker bob.

2. *The Auxiliary Pendulum.*—The stem of this pendulum is made of brass, the bob is of soft iron and, at the lower end of it, is attached a small platinum needle t for the purpose of closing the electrical circuit II. This bob can be moved up

and down along the stem and by varying the period of rotation, we can adjust the time of the beginning and the duration of the opening of the shutter.

3. *The Shutter.*—As shown in Fig. 4, the shutter consists

FIG. 3.

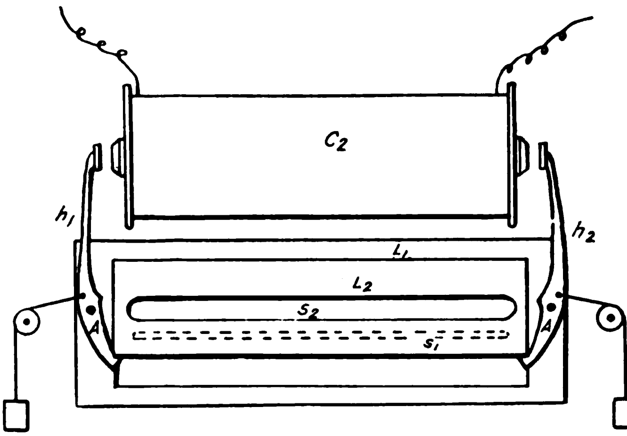


of two brass plates, the one L_1, fixed and having a rectangular slit s_1, 1×100 mm., while the other L_2 can move smoothly over the former, having a rectangular slit S_2, 10×110 mm. On both sides of the latter, two hooks h_1 and h_2 are provided, which are made of brass with pieces of soft iron at the upper ends of it and can rotate round axes A, A. By passing an electrical current through coil C_2 with a soft iron core, the movable slit L_2 falls down past the fixed slit L_1 and the light from the main pendulum and the magnifying lens falls on

the photographic film at the suitable moment and during the period of contact.

4. *The Rotating Cylinder.*—The rotating cylinder, round which the photographic film is wound, is a hollow circular

FIG. 4.

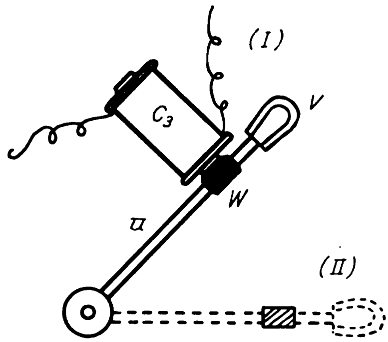


cylinder made of brass, its diameter being 10.5 cm. It rotates round an axis by means of a direct current motor of 0.1 h.p. and its revolutions can be varied from 200 to 400 per minute. The rotational velocity of the drum can be regulated by means of a system of pulleys, great care being taken to ensure the concentric rotation of the drum. The drum and the shutter system were enclosed in a wooden box.

5. *The Buffer System.*—To prevent the rebound of the main pendulum from the specimen, the following device was used. The buffer system was a brass bar U with an india-rubber cap V and soft iron piece W. The bar can be rotated freely about a pin O, near this bar, a fixed bent bar N of brass is in contact with a small sphere Z (Fig. 2) which is one end of the coil C_3, closing the circuit IV, which contains the bent bar and the coil C_3, the coil C_3 attracts the soft iron piece W of the buffer, as shown in the position I in Fig. 5, and if the auxiliary pendulum, after passing through the mercury pool breaks the contact between N and Z, the buffer falls to the position II which prevents the impinging sphere from striking the specimen a second time.

6. *The Tuning Fork.*—The tuning fork used was the usual type driven by a small electromagnet, and its frequency was 200.

FIG. 5.



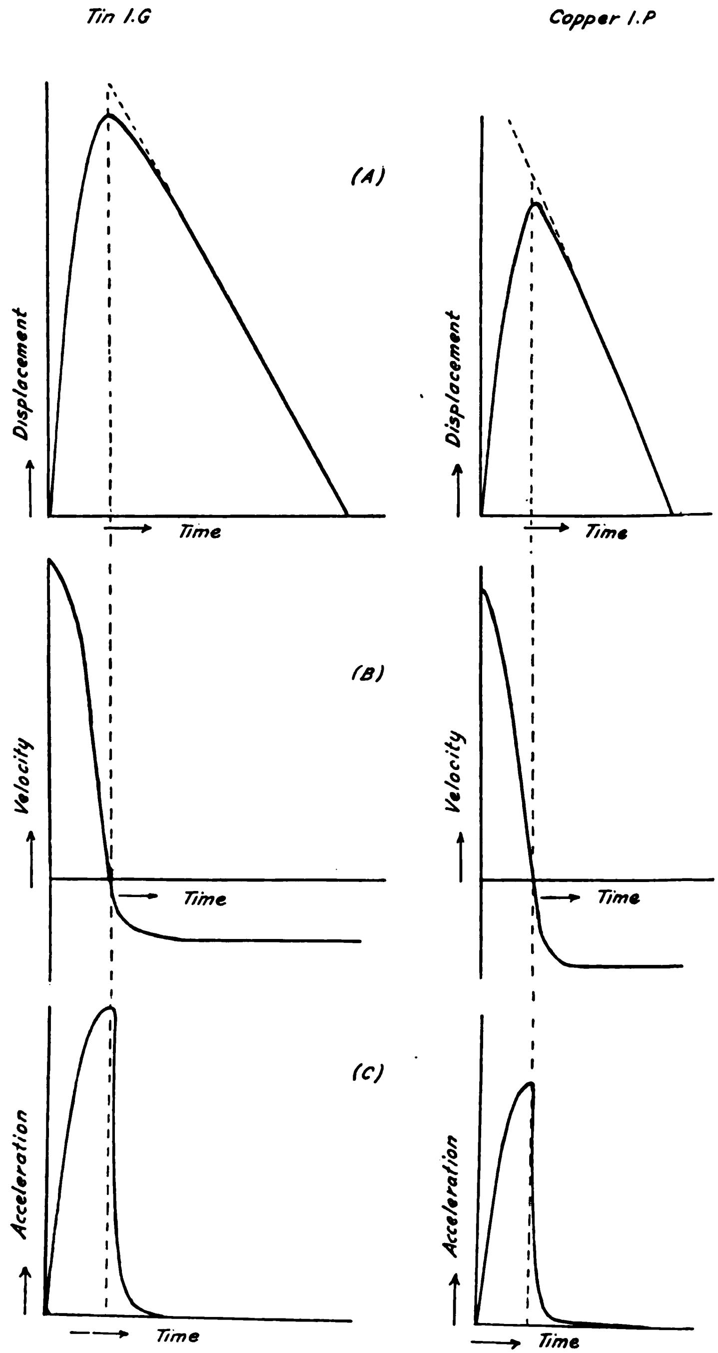
7. *The Specimen.*—The specimen tested was a circular cylinder 4 cm., in diameter, and the impact plane was polished with emery papers and firmly held in a vice.

3. EXPERIMENTAL RESULTS AND CONCLUSIONS.

At first the main pendulum was freely hung in its vertical position and the plane surface of the specimen to be tested was exactly brought in contact with the impinging sphere of the pendulum. The exactness of this contact was confirmed electrically by means of a sensitive tangent galvanometer. When the specimen was in this position, the light was allowed, by opening the shutter, to pass through the slit of the main pendulum and the magnifying glass, and thus the zero position of the indentation on the photographic film could be determined.

Next, the shutter being readjusted, the main pendulum was fastened to the staple and all parts of the apparatus well adjusted; the main pendulum was then set free from the staple and the record of its motion obtained. The specimens tested were cadmium, tin, aluminium, lead, phosphor-bronze, zinc, gunmetal, copper, soft iron, brass and indiarubber. By varying the condition of the experiment, that is, the initial velocity of the impinging sphere, the variation of velocities before and after the impact and the time of contact, the volume of the indentation, etc. were investigated.

FIG. 6.



Tin I.G
Copper I.P
(A)
Displacement
Time
Displacement
Time
(B)
Velocity
Time
Velocity
Time
(C)
Acceleration
Time
Acceleration
Time

The results are summarized as follows:

1. *The Time-displacement Curve and the Time-velocity Curve.*—The records which we have obtained directly by experiments are the time-displacement curve of the impinging sphere, that is the relation between the depth of the indentation and the time, some examples of the curves obtained in our experiment being given in Fig. 6 (*A*) and the annexed plate.

With the exception of indiarubber, the form of the curves for metals are all similar in character. Since the tangent at any point of this curve represents the velocity at that point of the indentation, we can obtain from these curves the relation between the velocity and the time as shown in Fig. 6 (*B*).

From these two figures, it can be concluded that the rate of the penetration is at first rapid and then gradually decreases. In other words, the rate of the decreases of the velocity of the impinging sphere is comparatively small in the first stage of penetration, but becomes greater in the last stage. After the maximum indentation has been reached, the direction of the motion of the sphere is reversed and its velocity gradually increases until it finally attains a constant value. The fact that the sphere regains some of the velocity, shows that some parts of the indentations elastically recover after the sphere has ceased to penetrate.

The velocity of the sphere increases as this recovery progresses, becoming finally a constant value.

It is therefore a very interesting question whether the forms of the indentation remain spherical or not. Experiments to solve this problem, by varying the materials both of the specimen and the impinging spheres, are now in progress and the result will be published in the near future.

2. *The Force-time Curves.*—Again differentiating the velocity-time curves mechanically, we obtain the force-time curves as shown in the Fig. 6 (*C*). The force in the contact surfaces increases at first slowly and then rapidly to a maximum value at the instant when the greatest indentation is produced and then decreases to zero. This result coincides with those obtained by H. Seehase [2] in his experiment on

[2] H. Seehase, *Forschungsarbeiten*, Vol. 182, 1915.

the deformation of materials which were struck by a falling body and that of A. Elmendorf's [3] timber break experiment, but in contrast to that of R. Planck [4] in the case of the extension of materials by a sudden loading. It will be observed that this method of measuring force requires two differentiations of the displacement-time curves and hence there may be a certain degree of ambiguity in the magnitude of these forces. But it is certain that the maximum of the force corresponds to the maximum depth of the indentation, in this respect, the differentiating instrument designed by Elemendorf is very valuable, but the direct measurement of the force is desired.

3. The relation between the volume of indentation and the loss of kinetic energy of the impinging sphere.

According to the results previously published, there exists approximately a proportional relation between the volume of the indentations remaining after the impact and the total loss of the kinetic energy of the impinging sphere. It is very interesting to find whether the same relation holds good at every instant of the impact.

TABLE I.

V(mm.^{3}).	$E(\times 10^6$ erg).					
	Al.	Sn.	Zn.	Cu.	Brass.	Soft Iron.
0.185	0.038	0.143	0.221	0.450	0.542	0.948
0.795	0.163	0.296	0.954	0.194	2.35	3.95
1.74	0.358	0.859	2.05	4.32	5.13	8.94
3.10	0.639	1.534	3.66	7.59	9.12	15.92
4.40	....	....	....	....	....	22.54
4.58	....	....	....	....	13.54	
4.75	0.974	2.33	5.68	11.65		
5.98	1.22	2.89	....			
6.10	....	....	7.34			
6.74	1.40	....				
7.55		3.68				
7.59		3.76				

From the displacement-time and the velocity-time curves, we can calculate the total loss of the kinetic energy E and

[3] A. Elmendorf, JOURN. FRANK. INST., Vol. 182, p. 771, 1916.

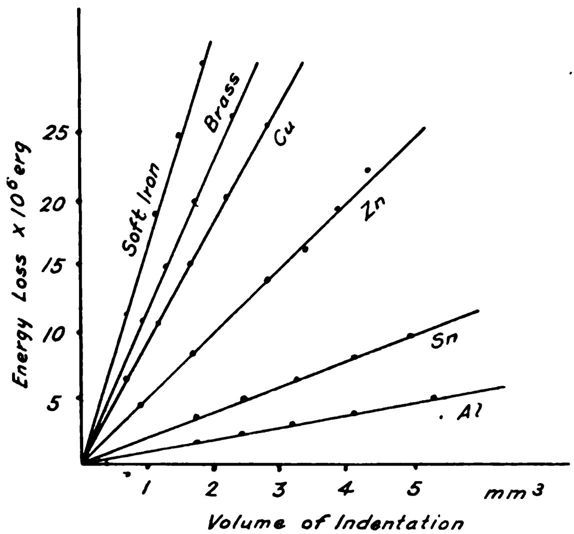
[4] R. Planck, *Forschungsarbeiten*, Vol. 133, 1913.

the volume of indentation at every instant of penetration; the result shows that a proportional relation approximately exists between them, and the constant of proportionality is different for different materials as shown in the table I, II, and Fig. 7. Thus it is concluded that the impinging sphere penetrates the other body so as to make the volume of the indentation proportional to the loss of the kinetic energy up to that instant. It is very interesting that this relation holds good not only for the volume remaining after the impact, but also for all the stages during the impact.

TABLE II.

	Pb.	Al.	Sn.	Zn.	Cu.	Phosphor Bronze.	Brass.	Soft Iron.
Energy Loss $\frac{10^6 \text{ erg}}{\text{mm.}^3}$	0.074	0.205	0.512	1.21	2.44	2.78	2.95	4.18

FIG. 7.



As Lord Rayleigh[5] has pointed out, the dissipation of energy during the impact is due to two causes: (a) the

[5] Lord Rayleigh, *Phil. Mag.*, Vol. 11, p. 283, 1906.

production of sound, (*b*) the strain caused during an inelastic collision The former is very small in comparison with the latter as Banerji [6] has shown, and if we leave this energy out of consideration, the dissipation of energy has to be ascribed entirely to the formation of the indentation. Thus the above result also confirms this conclusion.

Next, consider the resisting force of a body subjected to an impact. If we denote the mass of the impinging sphere by M, the velocity just before the impact and that at the instant when the depth of the indentation is x, by v_0 and v respectively, and the diameter of the circle of the indentation by y, the above mentioned conclusion can be expressed by the equation

$$K\int_0^x \pi Y^2 dx = \frac{1}{2} M(V_0^2 - V^2),$$

where K is the constant specified by the materials of the specimens.

Assuming that the resisting force is a function of the depth of the indentation and denoting it by $f(x)$, the work done by the impinging sphere during the penetration is expressed by

$$\int_0^x f(x)dx$$

and we have

$$\int_0^x f(x)dx = K\int_0^x \pi y^2 dx = \frac{1}{2} M(v_0^2 - v^2)$$

$$\therefore \quad f(x) = K\pi y^2.$$

Thus we obtain the following conclusion:

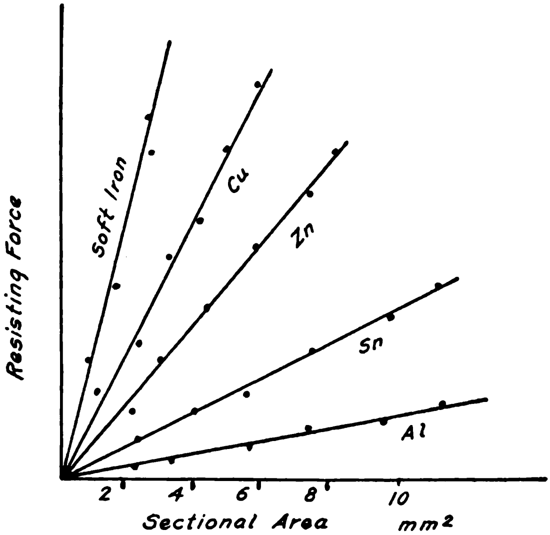
The resisting force due to the impinging sphere at a given depth of the indentation is proportional to the sectional area of the circle on the surface of the specimen at that instant.

Some examples of the graphical representation of the relation between the resisting force which were taken from Fig. 6 (*C*) and the calculated value of the area of the circle on the surface of the specimen at every instant of the indenta-

[6] S. Banerji, *Phil. Mag.*, Vol. 31, p. 96, 1916, and Vol. 35, p. 95, 1918.

tion are shown in Fig. 8, these curves confirming the above conclusion.

FIG. 8.



4. *The Time of Contact.*—The time of contact of the two bodies is next considered. As M. G. Moreau [7] has pointed out, there are three phases during impact; namely (1) the phase of penetration τ_1 during which the ball penetrates the material and its velocity diminishes from the initial value to zero, (2) the phase of reaction τ_2 during which the material react on the ball and the velocity increases from zero to a certain value, (3) the phase of release τ_3 during which the ball passes through a superficial layer of air up to the initial position, its velocity remaining constant.

From the displacement-time curve, we can evaluate directly the time intervals corresponding to these three phases; the results were as follows: (1) the total time of contact decreases as the velocity of the ball before the impact increases; (2) the phase of the reaction is the shortest, while the third phase is the longest of all; (3) the ratios of these three intervals are nearly constant for a given material, and independent of the initial velocity. This last result can

[7] M. G. Moreau, *Journ. d. Phys. et Radium*, Tome 11, p. 329, 1921.

TABLE III.

	Initial Velocity cm./sec.	τ_1 (sec.).	τ_2 (sec.).	τ_3 (sec.).	$\tau_2 : \tau_1$.	δ_1 (mm.).	δ_2 (mm.).	$\delta_2 : \delta_1$.	e.
Sn	168	13×10^{-4}	8×10^{-4}	46×10^{-4}	0.61	0.71	0.07	0.10	0.11
	174	12	8	47	0.67	0.82	0.08	0.10	0.11
Al	174	14	8	47	0.57	0.78	0.09	0.113	0.208
	174	13	7	48	0.54	0.86	0.10	0.116	0.209
Pb	168	21	10	123	0.47	1.86	0.10	0.054	0.083
	174	20	9	127	0.45	1.67	0.09	0.055	0.084
Zn	102	9	4	14	0.45	0.73	0.14	0.141	0.157
	124	8	4	15	0.50	0.73	0.14	0.141	0.155
Cu	102	7	4	16	0.57	0.75	0.10	0.134	0.313
	111	5	3	11	0.60	0.70	0.09	0.129	0.320
Soft Iron	124	4	3	8	0.75	0.63	0.10	0.158	0.373
	150	3	3	6	100	0.69	0.11	0.158	0.365
Brass	102	5	3	10	0.60	0.72	0.10	0.140	0.340
	111	7	4	8	0.57	0.73	0.10	0.140	0.340

be inferred from the fact that the ratios between the amounts of the penetration δ_1 and of restitution δ_2 are nearly constant for a given material. This is equivalent to the fact that the time of contact and the coefficients of restitution are nearly constant for different velocities beyond a certain value.

5. The results obtained in the case of indiarubber. In the previous investigation, it was noted that the behavior of indiarubber when subjected to impact, is somewhat different from the metals. The coefficient of restitution of the former is large as in the case of iron and copper, but the duration of contact is as long as one hundred times that of the latter. While, in the case of metal the shorter the duration of contact, the larger the coefficient of restitution.

In the present experiment also, the displacement-time curve and the velocity-time curve of indiarubber are somewhat different from those of metals as seen from Fig. 9. The characteristic point of the displacement-time curve is that no straight portion of the curve is observable in the third phase, and hence it seems probable that the sphere is accelerated beyond the zero line of contact. Thus we conclude that the specimen is put in a state of vibration by the local application of the impulsive force.

Since in the case of indiarubber, no indentation remains after the impact, it is clear that the energy consumed during the impact is mainly used up in the vibration of the specimen. Even in the case of metals, some energy will also be used in the vibration of the specimen, but it will be very small in comparison with that consumed in the indentation.

SUMMARY.

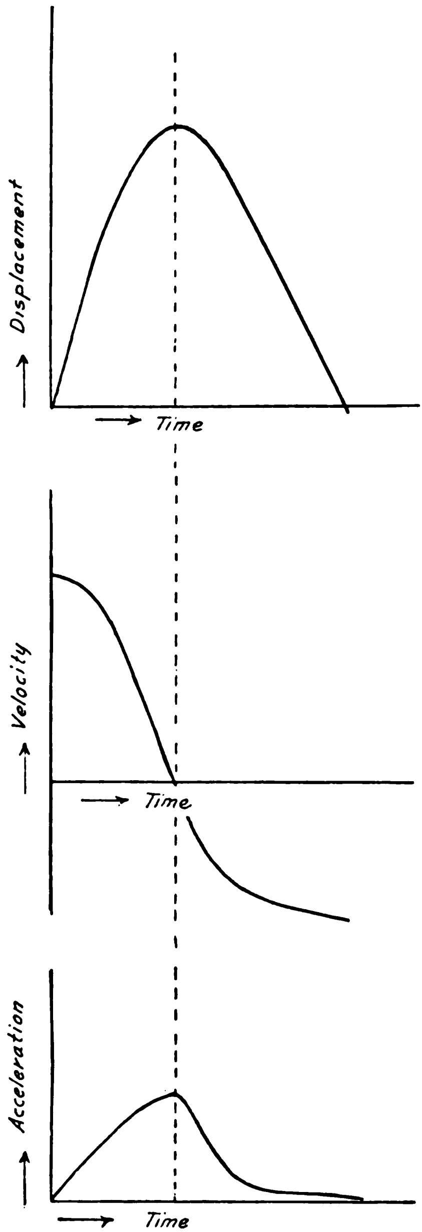
The main results of the present investigation are as follows:

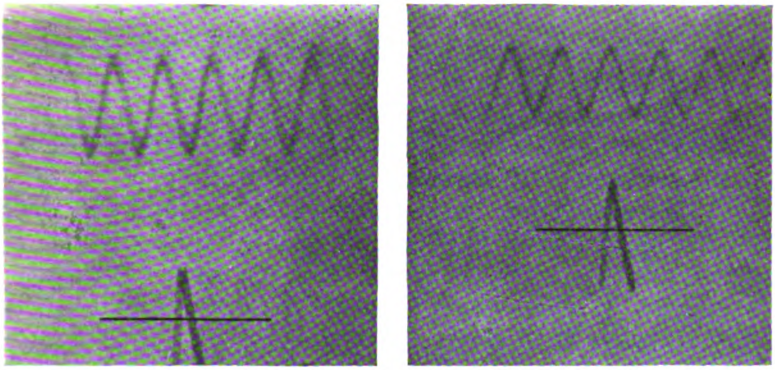
(1) The coefficient of restitution diminishes as the velocity just before the impact increases and beyond a certain value of this velocity, it diminishes linearly.

(2) The time of contact between the impinging sphere and the specimen diminishes as the velocity of the impact increases.

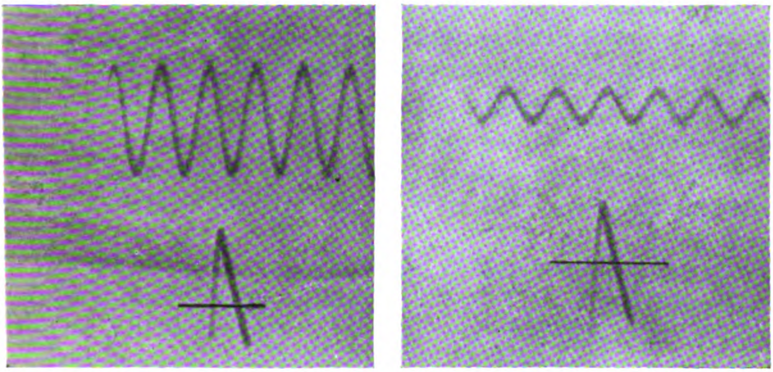
(3) In the case of impinging sphere, the volume of

FIG. 9.

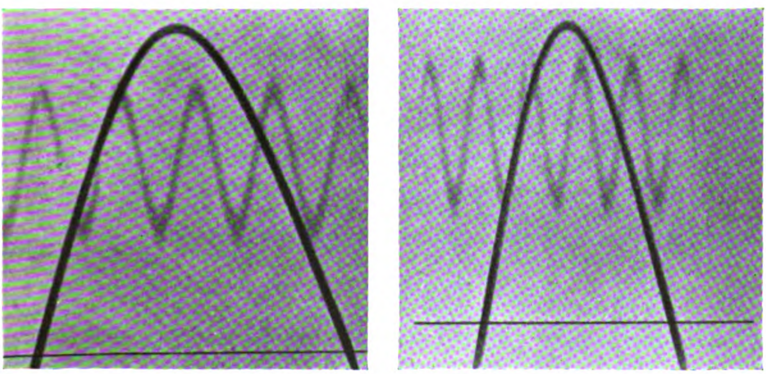




Brass. Initial vel. = 110 cm./sec.; magnif. = 13.8.
Soft iron. Initial vel. = 150 cm./sec.; magnif. = 13.8.



Zinc. Initial vel. = 102 cm./sec.; magnif. = 13.8.
Copper. Initial vel. = 150 cm./sec.; magnif. = 13.8.



Indiarubber. Initial vel. = 168 cm./sec.; magnif. = 13.8.
Indiarubber Initial vel. = 161 cm./sec.; magnif. = 13.8.

indentation is proportional to the total loss of kinetic energy up to that instant.

(4) The penetrating sphere is subjected to a resisting force which is proportional to the area of the circle on the surface of specimen at the instant of indentation.

(5) There are three phases of impact, the time of indentation, that of reaction, and that of release, among which the time of reaction is the shortest, and the time of release is the longest of all. The ratios of these three phases are nearly constant for a given material.

(6) In the case of indiarubber, the third phase is completely lacking and the impinging body is subjected to a further acceleration beyond the zero line of contact.

In conclusion, the writers express their hearty thanks to the Saito Gratitude Foundation, for one part of the expenses of the present experiment which was paid from the research fund of the Foundation.

A DETERMINATION OF A LIMIT OF THE NUMBER OF FREE ELECTRONS IN A METAL.*

BY

F. EVELYN COLPITTS.

THE original theories of metallic conduction of Riecke,[1] Drude[2] and J. J. Thomson[3] considered both thermal and electrical conduction as due to free electrons existing in metals with energy $\alpha\theta$ and obeying the ordinary gas laws. These simple theories have been found to explain certain facts such as the Wiedemann-Franz Law but have failed in many phenomena such as the Thomson effect, superconductivity and atomic heats. Other theories have gradually replaced the electron theory of metallic conduction, but recently Sommerfeld[4] has restored it by the use of the Fermi-Dirac statistical method. The concentration of free electrons varies for the different theories from 3 to 10^{-5} times the number of atoms.

The number of free electrons is here found from direct observations following a suggestion in J. J. Thomson's Corpuscular Theory of Matter. Although its practical application has necessitated considerable departure from the plan and theory of the experiment as there suggested, the basic principle holds.

On the free electron theory the charge on a body is the result of an excess or deficiency of free electrons. Ordinary electrostatics considers this charge as residing on the surface only. But, since the electrons are all negatively charged, they repel one another and consequently there is a finite thickness through which they diffuse due to the electronic pressure. The detailed theory shows that a difference of

* Part of a dissertation presented for the degree of Doctor of Philosophy in Yale University.

[1] E. Riecke, *Wied. Ann.*, *66*, 353 u. 545, 1898.

[2] P. Drude, *Ann. d. Physik*, 306, *1*, 566, 1900.

[3] J. J. Thomson, Rapports du Congres de Physique de 1900, Paris, *3*, p. 138.

[4] A. Sommerfeld, 'Naturwiss,' p. 825, 1927.

potential exists between any two points in the metal which correspond to different concentrations of electrons.

These considerations may be applied to the case of a thin film of metal on the inside of a glass cylinder. Suppose that the ends of the cylindrical film are continued into heavy collars of the metal and that an electric field is applied between the thin film and the layer of tinfoil surrounding the cylinder. Then, if the film is sufficiently thin, a portion of the charge density will penetrate to the inside and there will be a difference of potential between the inside of the film and the heavy collars. This difference of potential is found to be a function of n, the number of free electrons per unit volume. Hence either a definite value of n or, if a zero result is obtained for the potential difference to be measured, a definite lower limit for n may be determined.

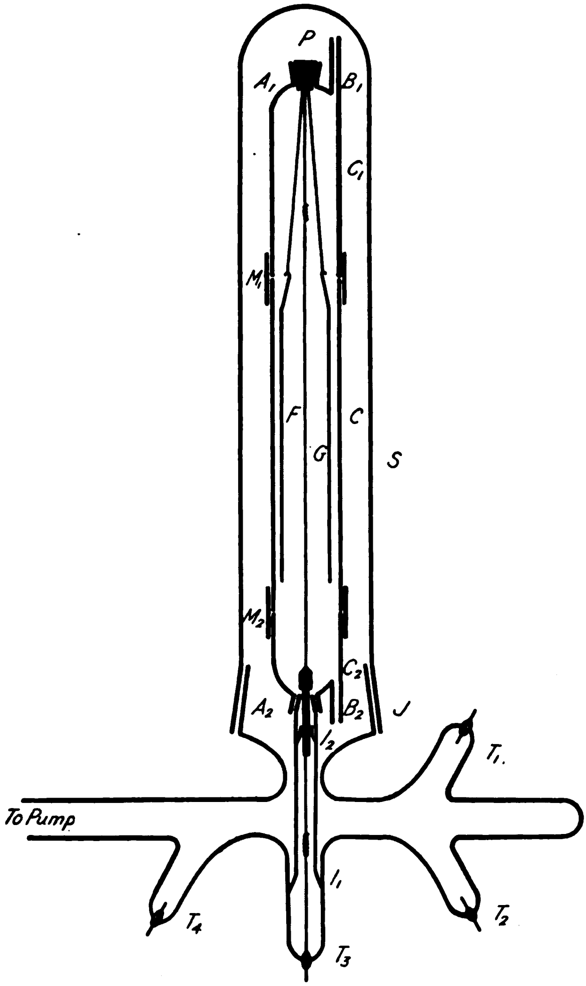
APPARATUS.

Fig. 1 gives the apparatus used for depositing the films. A large pyrex glass cylinder S rests on a ground glass joint J supported by a wooden frame. An inner seal I_1 supports a smaller tube ending in a ground glass joint A_2. Resting on A_2 is a glass cylinder C_2 and above it the glass cylinder C on which the film is to be deposited. Above C is another cylinder C_1 ending in the ground glass joint A_1. The parts are held together and aligned by iron wires passing around C_1, C, C_2 and screwed to M_1 and M_2, two metal collars fitting closely on the junctions of C with C_1 and C_2.

P is a steel plug resting in A_1. The glass guard G is hung from P by nickel wires, while the heavy collars are being deposited. The filament F is supported by a coiled copper wire from the center of P. The lower end is held by a pin vise passing through A_2 and held centrally by an inner seal I_2. Another coiled copper wire connects the pin vise to the tungsten seal T_3. When the apparatus is used for evaporating the films, P is connected to T_4. Fig. 1 gives the set-up for sputtering or evaporating the heavy films of metal on the glass cylinder C. For depositing the thin part of the film, the guard G was removed. For the purpose of measuring the resistance of the film during deposition, copper wires were soldered to the heavy films, passing through B_1 and B_2

and connected to T_1 and T_2 respectively. The whole apparatus was connected to a customary vacuum system consisting of a two stage mercury diffusion pump backed by a Cenco

FIG. 1.

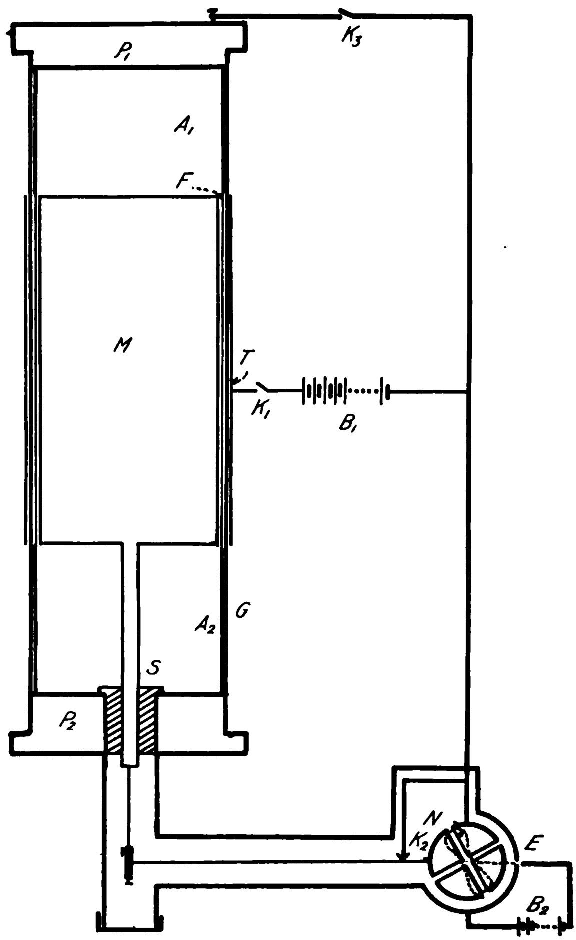


Hyvac Oil pump. Liquid air was always used during deposition of the films.

Fig. 2 shows the apparatus used for performing the main

experiment. F is the thin film deposited on the glass cylinder G, having heavy films A_1 and A_2 on the ends. P_1 and P_2 are brass discs which fit tightly in the glass cylinder and make

FIG. 2.



contact with the thin film through A_1 and A_2. M is a hollow brass cylinder with solid ends supported by a heavy rod through the sulphur plug S and connected to the quadrant electrometer E. T is a sheet of tinfoil wrapped around G and connected to the high potential battery B_1. N, the

needle of the electrometer, is connected to one pole of the constant potential battery B_2.

PROCEDURE AND RESULTS.

The thickness of the film was obtained by two methods:

(1) By weight. Either the increase in weight of the cylinder or the decrease in weight of the filament gives the thickness of the film assuming the same density as for the metal in bulk. These two methods agreed within 5 per cent. for gold. The first weight method did not work for tungsten.

(2) By comparison of its specific resistance with that of films of known thickness. This method is justified by the experiments of Mackeown [5] who shows that for films comparable in thickness with those here used, the apparent specific resistance has its normal value. This method was also checked by the weight method.

A 1000 volt battery was used for sputtering in the case of gold and a D.C. heating current for the evaporation of the tungsten.

When a film appeared uniform and had a resistance of the right value, it was used according to Fig. 2. Then, with K_3 closed and K_2 open, K_1 was closed and the deflection noted.

The potential corresponding to the deflection of the electrometer is not the same as the potential of the inside surface of the film but is related to it by the equation

$$V/P = -q_{vx}/q_{vv},$$

where V represents the potential on the electrometer system by raising the film to a potential P, and q_{vx} and q_{vv} are the usual coefficients of induction and capacity. This ratio was found by applying P directly to the electrometer and noting the deflection θ_2, then applying it to the film and noting the deflection θ_1 corresponding to V. Then the ratio is given by θ_1/θ_2. The value of the ratio varied between .71 and .79, the variation being due to slight differences in the set-up of the parts M and F, Fig. 2.

In the case of Gold No. 1, where a deflection was obtained, a test for actual holes in the film was made by using, instead of the sheet of tinfoil T, Fig. 2, a narrow band of copper. If

[5] S. Mackeown, *Phys. Rev.*, *23*, 85, 1924.

there were actual holes in the film, there should be certain positions of the copper band at which the electrometer would deflect suddenly. No such places were found. The tungsten film oxidized so rapidly that it was not tested in this way, but no holes or scratches could be noticed on it.

The resistance of the film played no part provided that it was not great enough to produce a difference of potential along the film due to the leakage through the glass. The conductivity of the glass was measured and the conduction current was only 10^{-8} amperes using 4000 volts. In the case of the gold films, the resistances were 10 and 16 ohms respectively. The resistance of Tungsten No. 1 was 150,000 ohms which might give a drop of potential along the film of 1.5×10^{-3} volts, but the measured change of potential of the film on applying the potential to the tinfoil was 4.8×10^{-2} volts. Hence no great part of it could be due to the high resistance of the film. The resistance of Tungsten No. 2 was only 10,000 ohms. In no case would the effect of the resistance explain the deflection obtained. Table 1 gives the actual results.

Table I.

Substance.	Potential Applied volts.	Electrometer Sensitivity mm/volt.	q_{zy}/q_{yy}.	Film Thickness cm $\times 10^{-6}$	Average Deflection mm.	ΔV e.s.u.
Gold No. 1.	3,280	1,334	.71	2.0	4.0	1.4×10^{-5}
"	2,000	1,334	.71	2.0	2.5	8.8×10^{-6}
Gold No. 4.	1,030	1,550	.78	1.5	0.0	$<2.8 \times 10^{-6}$
"	2,700	5,300	.78	1.5	0.0	$<8.1 \times 10^{-7}$
"	2,860	5,550	.78	1.5	0.0	$<7.7 \times 10^{-7}$
Tungsten No. 1	4,000	480	.79	7.5	24.0	2.1×10^{-4}
"	4,000	1,500	.79	7.5	59.0	1.7×10^{-4}
No. 2.	4,000	1,040	.79	9.9	0.0	$<4.1 \times 10^{-6}$
"	4,000	6,220	.79	9.9	0.0	$<6.8 \times 10^{-7}$
"	4,000	15,000	.79	9.9	0.0	$<2.8 \times 10^{-7}$

Thickness of glass cylinder = 1.2 mm.
< gives the value corresponding to 1 mm. deflection.

THEORY AND INTERPRETATION OF RESULTS.

Let n = the normal number of free electrons per cc. in a certain metal,

p = the electronic pressure at any point,

X = the electric field in any direction,

ξ = the increase in number per cc. at any point over the normal number

Then $p = RT(n + \xi)$ at any point and

$$\frac{dp}{dl} = RT\frac{d(n+\xi)}{dl} \text{ in any direction characterized by } dl. \quad (1)$$

Also

$$\frac{dp}{dl} = -(n+\xi)e\frac{dV}{dl}, \quad (2)$$

giving

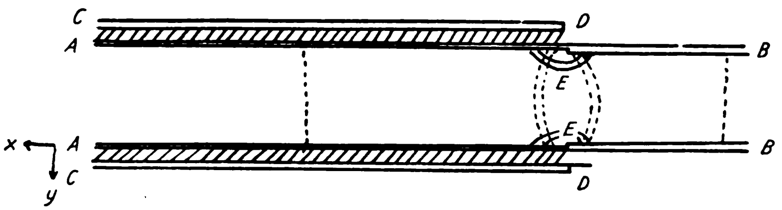
$$dV = -\frac{RT}{e}\frac{d(n+\xi)}{(n+\xi)}$$

or

$$V_2 - V_1 = -\frac{RT}{e}\log(n+\xi)\Big|_1^2. \quad (3)$$

Suppose this general equation is applied to the case of a thin sheet, or film of metal, AB, separated from another sheet CD by a dielectric, Fig. 3, CD is supposed to be connected

FIG. 3.



to a high potential battery, the other end of which is connected to AB. Then Eq. (3) will give the value of ΔV of the difference of potential between EB and any point in AE when the number of free electrons at that particular point is changed by the presence of CD. The field exists only near E, the junction of the thin part and the thick part, hence not far beyond this junction, both on the thin and the thick side, the equipotential surfaces will be infinitely far apart. The lines of force are represented by heavy lines and the equipotential surfaces by dotted lines.

We will then have

$$\Delta V = -\frac{RT}{e}\log\frac{n+\xi}{n} \quad (4)$$

since $\quad n$ = the electronic concentration in EB

$n + \xi$ = the electronic concentration in AE at the point considered.

The problem now reduces to that of finding ξ on the inner surface of the thin film when the thickness (η) of the film is known.

By Gauss' Theorem

$$\frac{d^2V}{dy^2} = -4\pi\xi e;$$

but from (3)

$$\frac{dV}{dy} = -\frac{RT}{e}\frac{d}{dy}\log(n+\xi);$$

hence

$$4\pi\xi e = \frac{RT}{e}\frac{d^2}{dy^2}\log(n+\xi)$$

or

$$\frac{1}{n+\xi}\frac{d^2\xi}{dy^2} - \frac{1}{(n+\xi)^2}\left(\frac{d\xi}{dy}\right)^2 = \frac{4\pi\xi e^2}{RT}, \tag{5}$$

which is our general equation for the evaluation of ξ, subject to the condition that

$$e\int_0^\eta \xi dy = Q, \tag{6}$$

where Q is the charge per unit area on AE.

Integrating equation (5), we obtain

$$\frac{\left(\frac{d\xi}{dy}\right)^2}{(n+\xi)^2} = \frac{8\pi e^2}{RT}(\xi - n\log(n+\xi) + C_1). \tag{7}$$

If it were true that $d\xi/dy = 0$ when $\xi = 0$, we could write $C_1 = n \log n$. This assumption would be invalid without further examination in the present instance, however; and, in general we must write

$$C_1 = n(\log n + C_3). \tag{8}$$

Equation (6) may then be written

$$\frac{\frac{d\xi}{dy}}{n+\xi} = \left(\frac{8\pi e^2}{RT}\right)^{1/2}\left(\xi - n\log\frac{n+\xi}{n} + nC_3\right)^{1/2}.$$

If the transformation $s = \log(n+\xi)/n$ is made, it becomes

$$\frac{ds}{dy} = (ne^s - n - ns + nC_3)^{1/2}\left(\frac{8\pi e^2}{RT}\right)^{1/2},$$

$$\frac{ds}{dy} = \left(\frac{8\pi e^2 n}{RT}\right)^{1/2}(e^s - 1 - s + C_3)^{1/2}, \qquad (9)$$

so that

$$\int_{s_1}^{s_2}\frac{ds}{(e^s - 1 - s + C_3)^{1/2}} = \left(\frac{8\pi e^2}{RT}\right)^{1/2} n^{1/2}(y_2 - y_1). \qquad (10)$$

Now, measuring y from the inside of the film, let $y_1 = 0$ correspond to s_1. Then, since $s = \log(1 + \xi/n)$, equation (4) yields

$$s_1 = \log\left(1 + \frac{\xi_1}{n}\right) = -\frac{\Delta Ve}{RT},$$

where ΔV is change of potential of the inside of the film on application of the external potential, and is the quantity yielded by experiment. Thus (8) becomes

$$\int_{-(\Delta Ve/RT)}^{S}\frac{ds}{(e^s - 1 - s + C_3)^{1/2}} = \beta n^{1/2}y + C. \qquad (11)$$

If we assign a tentative value of C_3, it is possible to evaluate the left hand side graphically as a function of its upper limit S. Thus, it becomes possible to plot S against $\beta n^{1/2}y + c$ for this tentative value of C_3. Since $S = \log(1 + \xi/n)$, it thus becomes possible to plot ξ/n against $\beta n^{1/2}y + c$ for the assumed C_3. Now the total charge Q per unit area of the film is given by

$$Q = e\int_0^{\eta}\xi dy$$

or, changing the variable

$$\frac{\beta Q}{en^{1/2}} = \int_C^{\beta n^{1/2}\eta + C}\frac{\xi}{n}d(\beta n^{1/2}y + c). \qquad (12)$$

Since, for the assumed C_3, we have ξ/n as a function of $\beta n^{1/2}y + C$, it is possible to plot ξ/n against $\beta n^{1/2}y + C$. If, still corresponding to the tentative value of C_3 we choose a tentative value of n, it is possible to find what value must be taken for C in order that when the integral on (8*b*) is graphically evaluated over the range C to $\beta n^{1/2}y + C$, the result so obtained is equal to the left hand side $\beta Q/en^{1/2}$. The value of ξ/n at the upper limit of the integral can then be found; and, if n has been chosen properly in relation to C_3, it should result that the use of the upper limit for ξ/n in (4) will give for ΔV a value equal to that yielded by experiment. If it does not, the procedure is to choose another value of n for the same C_3 and proceed in this way by interpolation until the correct value of n is found. In this manner, a number of possible n's corresponding to a various assigned C_3's could be obtained. The problem which remained was that of fixing C_3. How is this to be done?

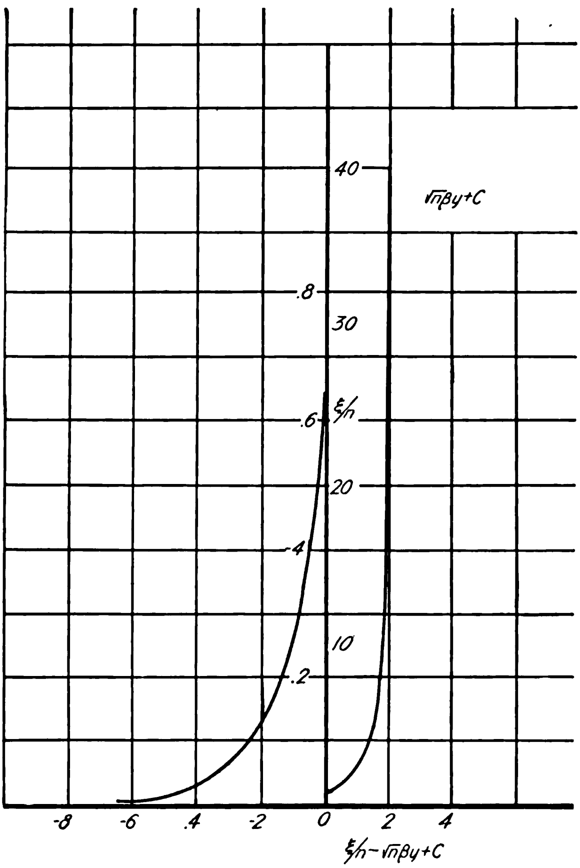
Now it will be observed that although equation (4) gives ΔV (i.e., $V_\eta - V_0$) quite explicitly as a function of ξ/n at $y = \eta$, it does not tell us that ΔV is entirely due to the charge on the film. Thus, for example, if concentrically with the cylinder, there had been a charged wire, the quantity $V_\eta - V_0$ would have been determined in part by the distribution of charge throughout the film and in part by the charge on the wire. Put in general terms the actual value of $V_\eta - V_0$ would in general be composed of two parts, a part calculable directly from the charge distribution throughout the film, and a part which was a solution of Laplace's equation and which would correspond to charged bodies outside the film. In the present instance, the only charged body outside the film, is the foil cylinder around the outside of the glass; and, since this produces no field in its interior, our $V_\eta - V_0$ is limited to the value calculable from the charge distribution on the film alone.

In other words, we must have

$$
\begin{aligned}
V_\eta - V_0 &= -\int_0^\eta 2\pi dy \int_0^y \xi e dy \\
&= -\frac{2\pi e n^{1/2}}{\beta}\int_0^\eta dy \int_c^{\beta n^{1/2}y+C} \frac{\xi}{n} d(\beta n^{1/2}y + C).
\end{aligned}
\qquad (13)
$$

Now for every value of C_3 chosen, we have a corresponding value of n and of C. Moreover, the graphs for evaluating the integral with C in the limits are the same as those used in connection with equation (8*b*), so that it is possible to evaluate this integral as a function of y and so evaluate, again graphically, the integral whose limits are zero and η. If the result is not equal to $V_\eta - V_0$ as measured experimentally, the assumed value of C_3 was wrong. We must then choose the value of C_3 whose corresponding n and C, chosen as they have been to satisfy (8*b*), also satisfy (8*c*). The corresponding value of n is then the value sought.

FIG. 4.



Proceeding in the above manner it was found that for gold film No. 4, and for the tungsten films, $C_3 = 0$. Fig. 4 shows the curve for ξ/n plotted against $\beta n^{1/2}y + c$ for the case $C_3 = 0$. By using the foregoing method, it is possible to show that for values of $n = 10^{17}$ for gold, the value of ΔV to be expected is 1.8×10^{-4} volt. The limiting value of ΔV experimentally observable was taken as 10^{-4} volt. Hence, the conclusion is that for gold, n must be greater than 10^{17} electrons per cc.

A simpler method is to find from Eq. (4) the value of ξ/n corresponding to the experimentally determined value of ΔV. Then the value of $\beta\sqrt{n}\eta + C$ is read directly from the graph. Fig. 4. Assigning a value to n, C is determined and the abscissa separation $\beta\sqrt{n}\eta$ is, moreover, fixed. The area corresponding to this separation is then measured. This should be equal to $\beta Q/e\sqrt{n}$. If not, the value of n was wrongly chosen. A trial method was used until the value of n assigned made the value of $\beta Q/e\sqrt{n}$ agree with that calculated from the area. This value of n is then the value in harmony with the experimental results using no approximations in its determination. Table 2 gives the values of n so determined for the four films studied.

TABLE 2.

Substance.	ξ/n (at $y =$).	Q e.s.u.	η cm.	$\beta\sqrt{n}\eta + C$.	n per c.c.
Gold No. 1	.101	26.5	2×10^{-6}	-2.32	3.6×10^{16}
Gold No. 4	.0096	35.8	1.5×10^{-6}	-5.65	$>1.6 \times 10^{17}$
Tungsten No. 1.	11.18	53.1	7.5×10^{-6}	1.80	1.4×10^{15}
Tungsten No. 2.	.008	53.1	9.9×10^{-6}	-5.85	$>9.2 \times 10^{15}$

Results for Gold No. 1 and Tungsten No. 1 are actual values while those for Gold No. 4 and Tungsten No. 2 are limiting values. In judging the reliability of the foregoing data, one must remember that an experiment of this kind can hardly be expected to give more than orders of magnitude. Then, in view of the known variability of the conductivity of thin films depending upon their previous treatment, it is not by any means remarkable that the two values for tungsten should be in apparent discordance, for tungsten films oxidize very rapidly in air, so that it is highly improbable that films 1 and 2 were in similar conditions.

If $\xi << n$ as assumed by J. J. Thomson, Eq. (6) reduced to

$$\Delta V = \frac{4\pi Q}{p}\frac{e^{-ph}}{1 - e^{-pn}} \quad \text{if} \quad p = \left(\frac{4\pi e^2 n}{RT}\right)^{1/2},$$

i.e., the difference of potential between any point $y = h$ and EB. But by using the detailed theory it is found that for values of $n = 10^{17}$ per cc. this approximation cannot be used, hence the graphical method must be used.

CONCLUSION.

The difference of potential between two points of a metallic conductor, having different concentrations of free electrons, was calculated as a function of n, the number of free electrons per unit volume in the metal. This difference of potential has been measured in two cases and in two others found to be zero. From the data obtained the lower limit of the number of free electrons in gold is of the order of magnitude of 2×10^{17}/cc., and in tungsten 9×10^{15}/cc. These results were obtained with a sputtered gold and an evaporated tungsten film.

In conclusion the author wishes to express her thanks to Professor W. F. G. Swann, who suggested the problem and helped materially toward its completion, also to many of the Department of Physics of Yale University for their coöperation.

SLOANE LABORATORY,
YALE UNIVERSITY,
May 31, 1928.

ERRATA.

AN EXPERIMENTAL INVESTIGATION OF FORCED VIBRATIONS.

BY

L. W. BLAU, M.A.

September, 1928, page 355.

Equation 5, page 557, should read

$$y(t) = \Big\{A^2 + B^2 + (C^2 + D^2)e^{-2Rt} - 2e^{-Rt}[(A^2 + B^2)(C^2 + D^2)]^{1/2} \sin \left[(s - \Delta n)t + \tan^{-1}\frac{C}{D} + \tan^{-1}\frac{B}{A}\right]\Big\}^{1/2} \sin (pt + \beta)$$

where

$$\beta = \tan^{-1}\frac{A + e^{-Rt}(C^2 + D^2)^{1/2} \sin \left[(s - \Delta n)t + \tan^{-1}\frac{C}{D}\right]}{B + e^{-Rt}(C^2 + D^2)^{1/2} \cos \left[(s - \Delta n)t + \tan^{-1}\frac{C}{D}\right]}$$

Fig. 21, page 371, should be Fig. 22 and Fig. 22 should be Fig. 21.

WHAT IS THE MAGNETIC PERMEABILITY OF IRON?

BY

T. D. YENSEN, Ph.D.

ABSTRACT.

This paper is a review of the changes brought about in the magnetic properties of "iron" during the period 1870 to 1928 and shows the absurdity of using "iron" as a standard for comparison. The latest (1928) value for the initial permeability (μ_0) of "iron" is given as 1150, its maximum permeability (μ_{max}) as 61,000, and its hysteresis loss (W_h) as 300 ergs per cubic centimeter per cycle for B = 10,000 gausses. The corresponding values prior to 1900 were: $\mu_0 = 250$ $\mu_{max} = 2600$, $W_h = 3{,}000$.

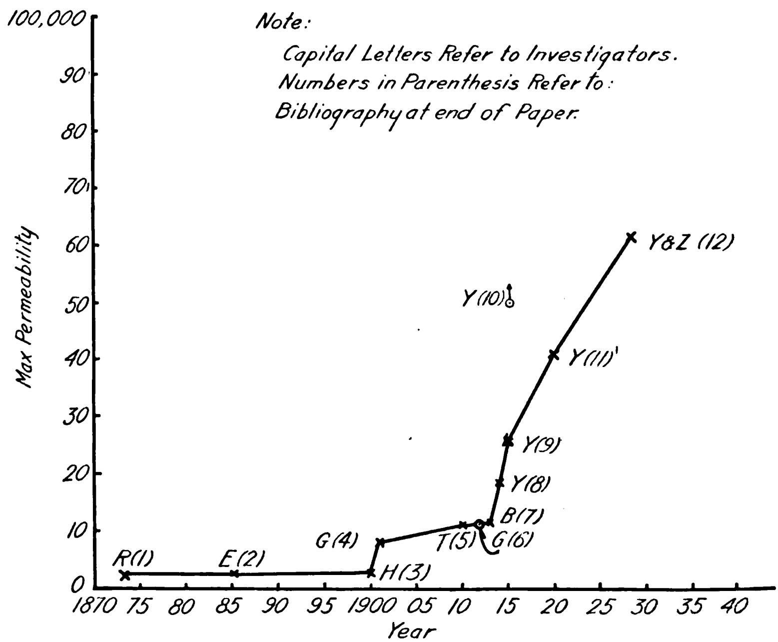
STATEMENTS have been repeatedly found in recent literature that some new alloy is a number of "times more magnetic than iron."* "Iron" is thus used as a standard for comparison, and it becomes interesting and important to inquire into the magnetic properties of this substance.

The writer has been working on this subject for the last fifteen years and has come to the conclusion that "iron" is about as unfortunate a material to use as a magnetic standard as can well be found. This becomes evident from the accompanying table and a glance at Figs. 1 and 2, giving a graphical representation of the change in maximum permeability and hysteresis loss of "iron" in the purest forms obtainable, during the period 1870 to date. When Ewing in 1885 thus talked about the magnetic properties of " iron " he mentioned a maximum permeability of around 2000,[1, 2, 3] which was the value imprinted on the writer's mind during his school days in the 90's. Between 1900 and 1910 there came new activity and interest in magnetic materials with the advent of silicon steel and electrolytic iron, and the maximum permeability of "iron" was gradually pushed to 10,000.[4, 5, 6, 7] Between 1910 and 1920 the writer, by taking additional precautions to prevent contamination of the electrolytic iron and to eliminate impurities, succeeded in increasing the maxi-

* See for example: *Science*, Vol. 57, p. 526, May 25, where this statement is found: ". . . permalloy, a new alloy of nickel, 100 times more magnetic than iron."

mum permeability of "iron" first to 19,000,[8] then to 25,000[9] and to 40,000,[11] and by the addition of small amounts of silicon (0.15 per cent.), obtained values greater than 50,000.[10]

FIG. 1.

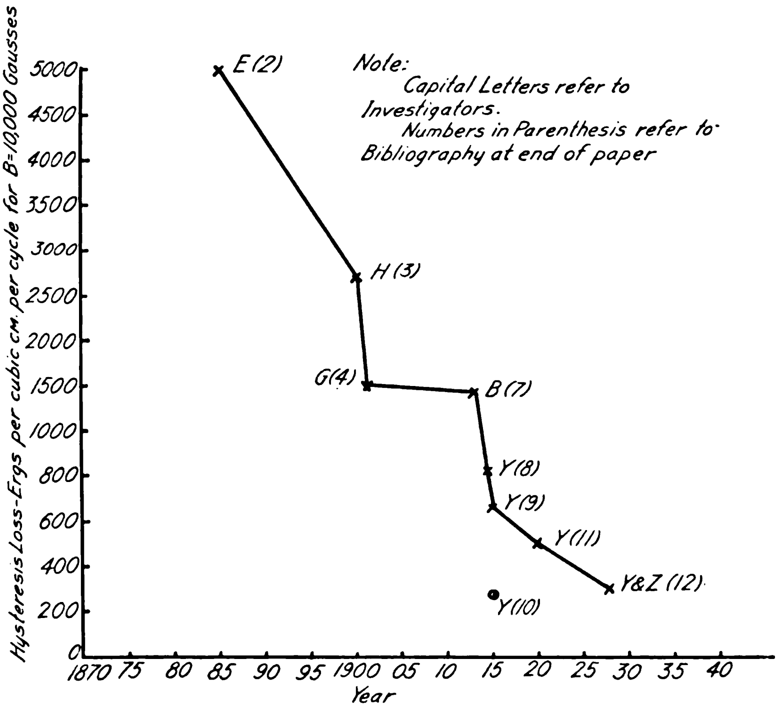


Maximum permeability of iron.

The effect of silicon was attributed to its cleansing action in removing oxides, and gave a hint that even greater values might be expected. By investigating the effect of minute quantities of impurities (C, P, S, Mn) and plotting the effect of carbon after eliminating the effect of the others the curves extrapolated to zero per cent. carbon indicated the possibility of zero hysteresis and enormous permeabilities for a single crystal of the element Fe.[11] Our approach to this goal will of necessity be assymptotic. Recently, by melting electrolytic iron with a small amount of carbon added (0.06 per cent.) in a high frequency vacuum furnace, designed and developed by P. H. Brace and N. Ziegler,[16] a sample was produced which after forging, machining into rings 2.5 × 1.9

× .3 cm. (1″ × ¾″ × ⅛″) and annealing at 900° gave a maximum permeability of 61,000, an initial permeability of 1150, and a hysteresis loss of 300 ergs per cubic cm. per cycle for $B = 10{,}000$. This is probably the purest sample of "iron" made to date, but is far from Fe, as it contains a

FIG. 2.



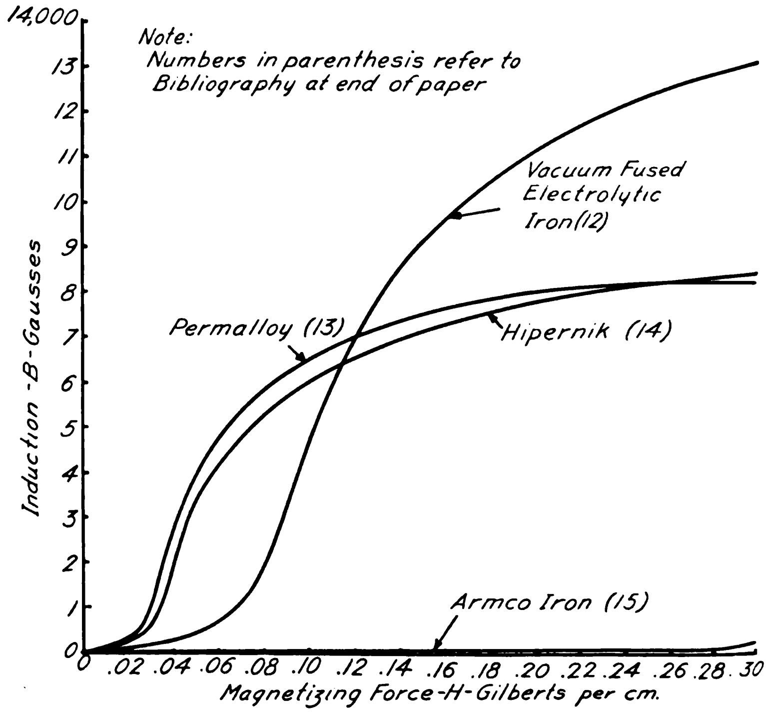
Hysteresis loss of "iron"

few thousandths per cent. carbon, some oxygen, and traces of sulphur, phosphorus, silicon and manganese. Its high magnetic quality may be due to its low oxygen content, obtained by the small addition of carbon and the high vacuum used in melting (0.0001 mm. Hg). So far we have no accurate data as to the oxygen and nitrogen content and their effect on the magnetic properties, but such data are now being collected.

In the above discussion the maximum permeability has

been used as a measure of the improvements; hysteresis loss could equally well have been used, as is seen in Fig. 2, decreasing from 5000 in 1885 to 300 in 1928. In either case the

FIG. 3.



B–H curves for various materials.

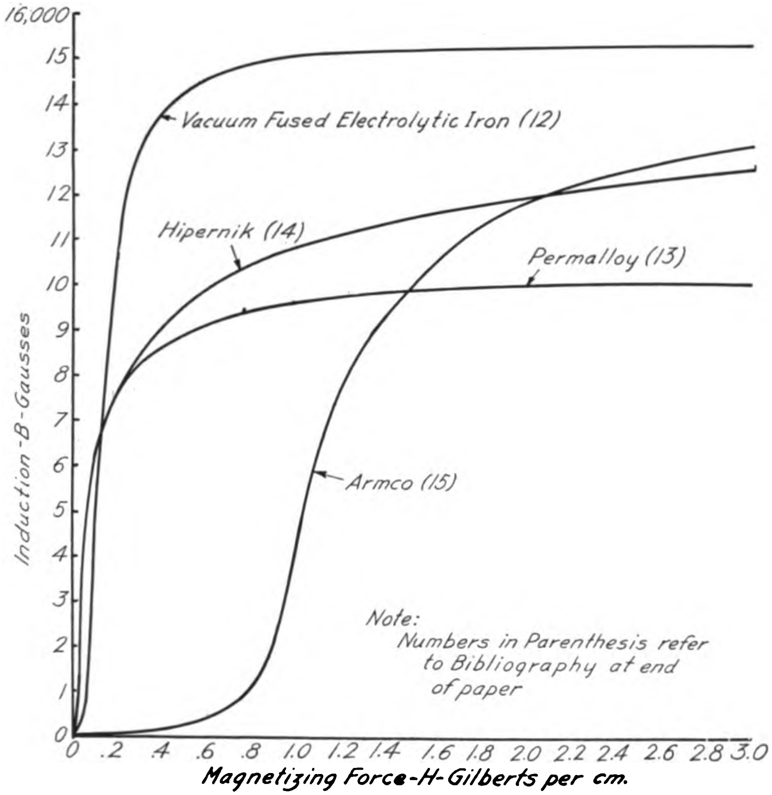
magnetic properties of "iron" have covered a range with a ratio of around 20 to 1 between the first and last representatives: max. permeabilities 2500 to 61,000, hysteresis loss 5000 to 300. Similarly, the initial permeability has been increased from a value less than 250 to 1150, a ratio of 5 to 1.

To use "iron" as a standard for comparison and to state for example that some alloy is 100 times more magnetic than it, is thus obviously meaningless, unless the particular kind of "iron" and the treatment to which it has been subjected are specified.

In Figs. 3, 4 and 5 are given B–H and μ–H curves for

four important materials: Armco iron (the purest commercial grade of iron available), vacuum fused electrolytic iron, Hipernik (50 per cent. Fe-Ni Alloy), and Permalloy (78½ per cent. Fe-Ni Alloy). The curves have all been obtained by the same method of testing (ballistic ring method) and

FIG. 4.



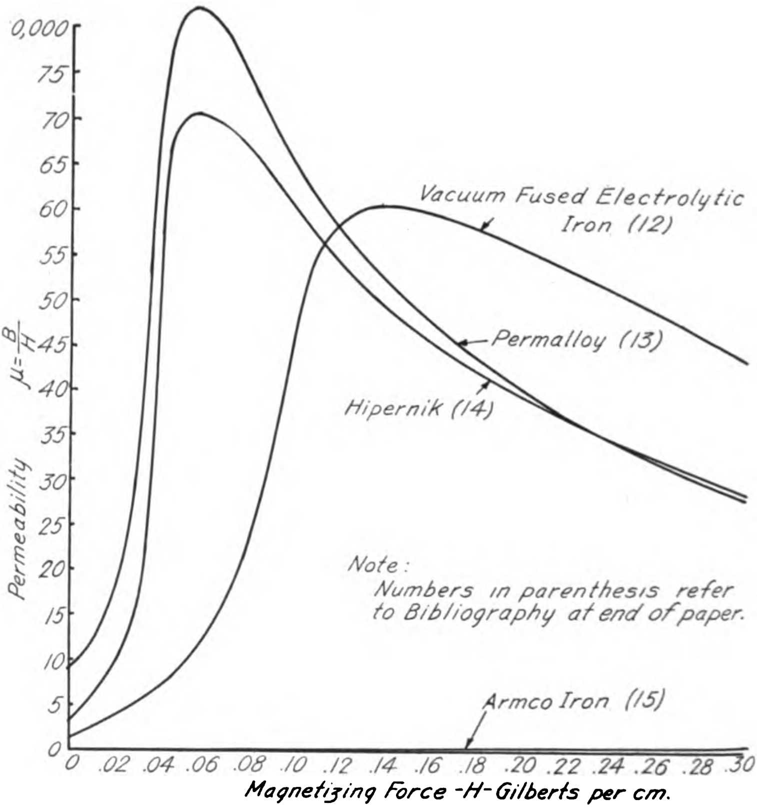
B–H curves for various materials.

are, therefore, directly comparable. The curves for Hipernik and Permalloy are not the best obtained,* but represent properties that are readily obtainable. The curves for vacuum fused electrolytic iron are the best ever obtained for this

* Arnold and Elmen [13] have mentioned max. permeabilities of 100,000 and initial permeabilities of 10,000 for Permalloy, and max. permeabilities above 80,000 have been obtained by the writer for Hipernik.[14]

material, but there is no reason to believe that they are the best obtainable when we know how to reduce the impurities still further, particularly carbon and oxygen, simultaneously. The curves for Armco iron are representative curves.*

FIG. 5.



Magnetic permeability curves for various materials.

In comparing these four materials we see from Fig. 5 that the expression "one hundred times more magnetic than iron" might be justified if we compare Permalloy or Hipernik with Armco or other commercial grades of iron for low values of *H*, but this expression can with equal justification be used in comparing the vacuum fused electrolytic iron with Armco

* Armco Ingot Iron is used for comparison because of its excellent magnetic properties particularly at high inductions for which the permeability approaches that for vacuum fused electrolytic iron.

Year	Investigator	Material	Max. Permeab. $\mu_{Max.}$	Permeability for H = 0	.01	.1	.5	1	For B = 10000 Coerc. Force Gilberts/cm.	Hyst. Loss Ergs/cc./cycle	Refer.*
				gilberts per cm.							
1873	Rowland	Wrought Iron	2,500								1
1885	Ewing	Wrought Iron	2,600							5,000	2
1900	Hadfield	Sw. Char. Iron	2,600				1,000	2,000	.92	2,700	3
1901	Gumlich and Schmidt	Wrought Iron	8,350						.50	Abt. 1,500	4
1910	Terry	Electrol. Iron as dep. and annealed	11,000								5
1912	Gumlich and Goerens	Sheets containing 0.4% Silicon	11,600						Abt. .45	Abt. 1,400	6
1913	Breslauer	Fisher Electrol. Iron as dep. and annealed	11,500				11,200	9,600		1,440	7
1914	Yensen (Univ. of Ill.)	Vacuum fused electrol. iron	19,000				18,800	12,500	Abt. .22	810	8
1915	Yensen (Univ. of Ill.)	Vacuum fused electrol. iron	25,800				23,600	14,000	.20	660	9
1915	Yensen (Univ. of Ill.)	Vacuum fused electrol. iron with .15% silicon added	50,000				27,000	14,500	.09	290	10
1920	Yensen (W. E. & M. Co.)	Vacuum fused electrol. iron	41,500			1,700	27,000	14,600	.17	500	11
1928	Yensen and Ziegler (W. E. & M. Co.)	Vacuum fused electrol. iron	61,000	1,150	2,600	46,600	28,600	15,500	.09	300	12
	For Comparison: Permalloy (78% Ni) and Hipernik (50% Ni) and Armco Iron.										
1923	Arnold and Elmen	Permalloy (78% Ni)	87,000	9,000	12,000	65,000	18,000	9,500	.05±	180±	13
1925	Yensen	Hipernik (50% Ni)	70,000	3,000	6,100	60,000	19,000	10,000	.05	200	14
1920 1916	Arnold and Elmen Yensen	Armco Iron	7,000	250	260	320	1,000	4,300	.72	2,100	15

* See Bibliography at end of paper.

iron. For $H = .15$, for example, the permeability of the latter is 260 while that of the former is 60,000, i.e., the ratio is as 1 to 230. In other words, one "iron" is 230 "times more magnetic" than another "iron," and the difference in permeability between these two kinds of iron is greater than that between the best "iron" and Permalloy or Hipernik for any value of H except perhaps for $H = 0$.

As far as the utility of this remarkably good "iron" is concerned, nothing much can be said at the present time because of its great susceptibility to other elements, principally carbon, oxygen, and perhaps nitrogen. Aside from the difficulty of its preparation in the first place, it is very difficult to obtain it in the form of thin sheets without ruining the magnetic properties beyond repair, largely because of oxidation and grain refinement. But it is of great scientific value. The results obtained confirm the prediction as to the magnetic properties of Fe, and thereby help us another step forward on the difficult road to an understanding of the nature of ferro-magnetism. It has been thought that the initial bend of the ordinary B–H curve (as illustrated for Armco iron in Fig. 4, for $H = 0$ to 0.8) is an inherent characteristic of "iron." Now we see that the purer we make the "iron," the less pronounced this initial bend becomes, and it is not inconceivable that it may disappear for the perfect Fe crystal.

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THE EQUATION OF STATE OF A MIXTURE DETERMINED FROM THE EQUATIONS OF STATE OF ITS CONSTITUENTS, AND ITS APPLICATION IN DETERMINING THE PHYSICAL AND CHEMICAL PROPERTIES OF A MIXTURE IN TERMS OF THOSE OF THE CONSTITUENTS.

BY

R. D. KLEEMAN, B.A., D.Sc.

§ 1. THE RELATION OF VOLUME AND MASS IN THE EQUATION OF STATE OF A MIXTURE.

THE equation of state of a mixture in its most general form involving M_a gram atoms of the constituent a, M_b gram atoms of the constituent b, etc., which may combine to form various molecules, is

$$p = \psi(T, v, M_a, M_b, \cdots), \tag{1}$$

where p, v, and T denote respectively the pressure, volume, and absolute temperature T of the mixture. Since the pressure p does not depend on the total masses of the constituents, but on their partial densities, the quantities v, M_a, M_b, $\cdots$ are associated with each other in the form of the ratios M_a/v, M_b/v, $\cdots$, and hence equation (1) should be written

$$p = \psi\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right). \tag{2}$$

§ 2. PROPERTIES OF THE EQUATION OF STATE IN RESPECT TO THE TEMPERATURE

If the masses M_a, M_b, $\cdots$ of the constituents are all zero while v remains finite, p is zero, and hence p may not be a function of T alone. The temperature T therefore appears in the equation only in functions of T which are factors of the ratios M_a/v, M_b/v, $\cdots$, or the foregoing equation should be written

$$p = \psi\left(A_1\frac{M_a}{v}, A_2\frac{M_a}{v}, \cdots B_1\frac{M_b}{v}, B_2\frac{M_b}{v}, \cdots\right), \tag{3}$$

where $A_1, A_2, \cdots B_1, B_2, \cdots C_1, C_2, \cdots$ are functions of T. These functions should initially be looked upon as being entirely independent of each other. If relations exist between them, they would be expressed by separate equations whose existence we need not consider at present.

§ 3. THE GROUPING OF THE TERMS OF THE EQUATION OF STATE, AND ITS FINAL FORM.

Suppose that the constituents $b, c, \cdots$ become the same in nature as the constituent a. The functions $B_1, B_2, \cdots C_1, C_2, \cdots$ then become the same in nature as the functions $A_1, A_2, \cdots$. It will not lessen the generality of the investigation if we suppose that under these conditions $B_1 = A_1$, $B_2 = A_2, \cdots C_1 = A_1, C_2 = A_2, \cdots$, etc. Let us now write $M_b = h_b M_a$, $M_c = h_c M_a, \cdots$. We are under these conditions dealing with $(1 + h_b + h_c + \cdots) M_a$ gram atoms of the substance a. The function ψ in equation (3) should therefore possess the property expressed by the equation

$$\psi\left(A_1\frac{M_a}{v}, A_2\frac{M_a}{v}, \cdots A_1 h_b\frac{M_a}{v}, A_2 h_b\frac{M_a}{v}, \cdots\right)$$
$$= \psi\left(A_1(1 + h_b + h_c + \cdots)\frac{M_a}{v},\right.$$
$$\left. A_2(1 + h_b + h_c + \cdots)\frac{M_a}{v}, \cdots\right). \quad (4)$$

This is realized only if equation (3) has the form

$$p = \psi\left(\frac{A_1 M_a + B_1 M_b + \cdots}{v}, \frac{A_2 M_a + B_2 M_b + \cdots}{v}, \cdots\right). \quad (5)$$

as can easily be shown by trial.

From this equation the equations of state of the constituents in the pure state may be obtained by writing the masses of the constituents zero except one, giving

$$\left.\begin{aligned} p_a &= \psi\left(A_1\frac{M_a}{v}, A_2\frac{M_a}{v}, \cdots\right), \\ p_b &= \psi\left(B_1\frac{M_b}{v}, B_2\frac{M_b}{v}, \cdots\right), \\ &\cdots\cdots\cdots\cdots \end{aligned}\right\}\cdots \quad (6)$$

where p_a, p_b, $\cdots$ denote their pressures. These have, it will be noticed, the same functional form, which is therefore independent of the nature of the mixture, or pure substances, we are dealing with.

Hence if the equations of state of a number of pure substances be known, the equation of state of any given mixture of these constituents may immediately be written down.

It should be noticed that the temperature function A_1 need not be the same in form as the temperature function B_1, and A_2 not the same in form as B_2, etc. But the number of functions A_1, A_2, $\cdots$ must be equal to the number of functions B_1, B_2, $\cdots$, etc., since the form of ψ is independent. This number is probably small. Meslin[1] has shown that any equation of state which contains three constants-equal in number to the variables temperature, volume, and pressure, which determine the state of the substance, gives the relation of corresponding states. From what we know of this relation it appears that it holds most exactly for non-dissociated and non-polymerized substances. Since the form of ψ is independent we may determine it from such substances, each of which contains atoms of one kind only. It appears, therefore, that the number of functions A_1, A_2, $\cdots$, etc., is probably not greater than three, and if greater, three of them only are of considerable importance.

The foregoing result may be obtained by another method which is instructive. The atoms of a pure substance a may be divided into two parts of masses M_a' and M_a'', in which case the first of equations (6) may be written

$$p_a = \psi\left(\frac{A_1M_a' + A_1M_a''}{v}, \frac{A_2M_a' + A_2M_a''}{v}, \cdots\right).$$

Now let us suppose that the atoms a of mass M_a'' get their nature changed and become atoms b, whose mass will now be written M_b and that of the remaining atoms written M_a. In the case that $M_a'' = M_b = 0$ the equation should give the equation of state of the pure substance a of mass M_a. Hence the process of the molecules a of mass M_a'' becoming molecules b will not change the factors of the M_a''s in the foregoing equation, nor change the functional form of ψ.

[1] *Compt. rend.*, 116, 135 (1893).

But the factors of the M_a'''s will change and may now be written B_1, B_2, $\cdots$, since when $M_a' = M_a = 0$ the equation should give the equation of state of the pure substance b. Thus finally the equation of state of a mixture of substances a and b has the form

$$p = \psi\left(\frac{A_1M_a + B_1M_b}{v}, \frac{A_2M_a + B_2M_b}{v}, \cdots\right).$$

§ 4. ON THE NUMBER OF FORMS OF ψ.

The number of equations of state expressing one variable as a function of the other variables corresponding to a given mixture of constituents (which may be wholly or partly combined with each other) may be greater than unity. This is definitely shown by the existence of isomers. Moreover, we have good reason to believe that in certain cases the constituents of a mixture may be in perfect equilibrium at a certain temperature without combining with each other, but that when the temperature is raised beyond a certain point combination takes place, and the resultant molecules remain in perfect equilibrium when the temperature is lowered to its initial value. It is difficult to prove this because a mixture of substances may appear to be in perfect equilibrium when actually combination is taking place, though extremely slowly. The various functional forms of ψ in equation (5) most likely correspond to the roots of p when the equation of state is written in a form not involving the extraction of roots.

It is also not improbable that the equation of state may have different forms only over a certain range of volume and temperature. This would mathematically be expressed by

$$p=\psi\left(\frac{A_1M_a+B_1M_b+\cdots}{v}, \frac{A_2M_a+B_2M_b+\cdots}{v}, \cdots Z\right), \quad (7)$$

$$\phi\left(Z, \frac{A_1M_a+B_1M_b+\cdots}{v}, \frac{A_2M_a+B_2M_b+\cdots}{v}, \cdots\right)=0, \quad (8)$$

where the number of real values of Z depends on the values of the variables T, v, M_a, $\cdots$. The equations of state of the constituents would have a corresponding number of different forms.

The subject is manifestly an important one, especially in connection with the present investigation, but about which we know little or nothing. It is therefore desirable that it should be systematically investigated. This might lead to the discovery of the exact forms of the function ψ, which is of fundamental importance, and whose discovery would correspond to a great advance in science. An empirical form is permissible only under certain conditions for obvious mathematical reasons.

§ 5. THE APPLICATION OF AN EMPIRICAL SERIES FORM, AND VAN DER WAALS' FORM OF THE EQUATION OF STATE.

These forms are likely to give fair results when the constituents of a given mixture combine only to a slight extent, or not at all. Thus let us consider a mixture of the two constituents a and e which do not combine with each other, and whose equations of state in the form of series when isolated are

$$p_a = A_1\frac{M_a}{v} + A_2\left(\frac{M_a}{v}\right)^2 + \cdots, \tag{9}$$

$$p_e = E_1\frac{M_e}{v} + E_2\left(\frac{M_e}{v}\right)^2 + \cdots, \tag{10}$$

where $A_1, A_2, \cdots E_1, E_2, \cdots$ are functions of T. The equation of state of the mixture would then be

$$p = \frac{A_1M_a + E_1M_e}{v} + \frac{(\sqrt{A_2}M_a + \sqrt{E_2}M_e)^2}{v^2} + \cdots. \tag{11}$$

It should be pointed out that we cannot write $A_2 = A_2'A_2''$ and $E_2 = E_2'E_2''$ in equations (9) and (10) in order to obtain for the corresponding term in the equation of state of the mixture $(A_2'M_a + E_2'M_e)(A_2''M_a + E_2''M_e)1/v^2$, which is indeterminate since we may give to A_2' and E_2' any value we please. It will be recognized now that in all cases in passing from the equations of state of the constituents to that of the mixture it must be done in such a way that no ambiguity arises.

Fair results should also be obtained with a series form of the equation of state in the case of an interacting mixture, if

we knew the nature and proportion of the various molecules present, and the complex molecules are sufficiently stable that their equation of state when isolated can be obtained. Thus suppose that in a mixture of molecules a and e molecules ae are formed, and that it contains M_a, M_e, and M_{ae} mols of the molecules a, e, and ae respectively. And suppose that the molecules ae in the isolated state decompose so slowly that their equation of state may be obtained, which expressed as a series would be

$$p_{ae} = X_1 \frac{M_{ae}}{v} + X_2 \left(\frac{M_{ae}}{v}\right)^2 + \cdots, \tag{12}$$

where X_1, X_2, $\cdots$ are functions of T. The equation of state of the mixture is then given by

$$p = \frac{A_1 M_a + E_1 M_e + X_1 M_{ae}}{v} + \frac{(\sqrt{A_2} M_a + \sqrt{E_2} M_e + \sqrt{X_2} M_{ae})^2}{v^2} + \cdots. \tag{13}$$

But it should be remembered that if we knew the exact forms of the function ψ the equations of state of such a mixture, ifs in equilibrium, would immediately be given by equation (5).

This method may also be applied to a mixture which is not in perfect equilibrium, but undergoes slow changes in molecular constitution.

If the van der Waals' equations of state of the pure substances a and e are given by

$$p_a = \frac{M_a RT}{v(1 - b_a M_a/v)} - \frac{a_a M_a^2}{v^2}, \tag{14}$$

$$p_e = \frac{M_e RT}{v(1 - b_e M_e/v)} - \frac{a_e M_e^2}{v^2}, \tag{15}$$

where b_a and a_a denote the co-volume and intrinsic pressure constant of the substance a, and b_e and a_e the corresponding quantities of the substance e, the equation of state of the mixture is

$$p = \frac{(M_a + M_e)RT}{v(1 - b_a M_a/v - b_e M_e/v)} - \frac{(\sqrt{a_a} M_a + \sqrt{a_e} M_e)^2}{v^2}. \tag{16}$$

This equation is likely to hold only for true mixtures, to an extent depending on the closeness the facts may be represented by an equation of the van der Waals' type. Applications of the equation will be given in a subsequent paper.

§ 6. FURTHER DIRECT APPLICATIONS OF THE RESULTS OF SECTION 3.

(*a*) The nature of the phases into which a mixture divides may be determined from the continuity equation of state of the mixture, or from the kind of equation we are dealing with in this paper, i.e., equation (5), by a method that will be published in a separate paper. It follows therefore that if the nature of the function ψ were known the nature of the phases of a mixture could be determined from the equations of state of the constituents. When there is little chemical interaction between the constituents this determination may be carried out by means of a series form of the equation of state dealt with in the previous Section.

(*b*) Another important application of equation (5) is the determination of the equation of state of an *interacting gaseous* mixture containing various molecules, from the equations of state of the constituents. But the latter equations correspond approximately to the equation of a perfect gas. It does not therefore seem possible at first sight that an equation which does not obey the gas laws could be deduced from these equations. But that this is mathematically possible will appear from considering the term

$$1/1 - e^{\left(\frac{A_1M_a+E_1M_e}{v}\right)^2},$$

which we will suppose forms part of the equation of state of a mixture of substances a and e. If the expression $A_1M_a + E_1M_e$ is small, in which case A_1 and E_1 have opposite signs, the exponential term is nearly equal to unity, and the whole term therefore large. If we write $M_e = 0$ in the term it becomes

$$1/1 - e^{\left(\frac{A_1M_a}{v}\right)^2}$$

and is then a term in the equation of state of the pure substance a. Now although the expression just considered may be small it does not follow therefore that the term $(A_1M_a/v)^2$

also is small, in fact it may have a large value. In that case the exponential term is large, and the whole term small. Similarly if we write $M_a = 0$ in the term it becomes one of the terms of the equation of state of the pure substance e. The value of its exponential term is large because the difference between A_1M_a/v and E_1M_e/v is small, and hence the value of the whole term is small. Thus this term will be of negligible value in the equations of state of the constituents, but not in the equation of state of the mixture.

It will be recognized now how important it is to discover the exact forms of the function ψ, and why empirical forms will not be of use in many cases. The stated problem can therefore at present be solved theoretically only. Its solution is very important because it would enable us to determine the nature of the molecules that may be formed in the gaseous state from given constituents by considering their equations of state in the pure state.

(*c*) Equation (5) may also be used to calculate the specific heat of a mixture by the help of the well known equation

$$\frac{\partial u}{\partial v} = T\frac{\partial p}{\partial T} - p, \tag{17}$$

where u denotes the internal energy of the mixture at the pressure p, volume v, and absolute temperature T. On multiplying this equation by ∂v and integrating it between the limits v and ∞ it may be written

$$u_\infty - u = \int_v^\infty \left\{ T\frac{\partial p}{\partial T} - p \right\} \partial v, \tag{18}$$

where u_∞ denotes the internal energy of the mixture at infinite volume. On differentiating this equation with respect to T at constant volume it becomes

$$c_{v\infty} - c_v = T\int_v^\infty \frac{\partial^2 p}{\partial T^2} \cdot \partial v, \tag{19}$$

where $c_{v\infty}$ and c_v denote the specific heats of the mixture at the constant volumes v and ∞ respectively. For p we may now substitute from the equation of state of the mixture derived from the equations of state of the constituents. It

remains to determine $c_{v\infty}$, which can be shown to be equal to the sum of the specific peats of the isolated constituents.

The expression for the internal energy u must possess the property that if the masses of the constituents are increased n times at constant pressure, in which case the volume is increased n times, the value of u is increased n times. This is realized if the expression has the form

$$u = M_a \cdot \psi_a\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right) + M_b \cdot \psi_b\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right) \\ + \cdots M_a \cdot \phi_a(T) + M_b \cdot \phi_b(T) + \cdots, \tag{20}$$

or

$$u = \Sigma M \cdot \psi\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right) + \Sigma M \cdot \phi(T). \tag{21}$$

The value of the internal energy at infinite volume is obtained by writing $v = \infty$ in the foregoing equations. The value of the internal energy of the isolated constituent a at infinite volume is obtained on writing $M_b = 0$, $M_c = 0$, $\cdots$, and $v = \infty$ in these equations, and so on for the other constituents. Now the value of the function ψ_a is evidently the same in each case, and this also holds for the other functions. The internal energy of the mixture at infinite volume is therefore equal to the sum of the internal energies of the isolated constituents. It immediately follows that this holds also for the specific heats.

An important extension may be made of the foregoing investigation. Suppose that the mixture is subjected to a magnetic field and that u represents the internal energy due to the presence of the field. It can be shown as before that an equation of the form (20) should hold. Similarly as before it follows then that the magnetic energy of the mixture at infinite volume is equal to the sum of the magnetic energies of the isolated constituents. If an electric field is applied instead of a magnetic field it can similarly be shown that the electric energy of the mixture at infinite volume is equal to the sum of the electric energies of the isolated constituents.

§ 7. THE DETERMINATION OF THE PHYSICAL PROPERTIES OF A COMPLEX SUBSTANCE FROM THE CORRESPONDING PROPERTIES OF THE CONSTITUENTS.

It should be possible to express every property of a complex substance in terms of the same properties of the constituents. For evidently there cannot exist any property of the substance the possibility of which did not exist in the molecules or atoms of the constituents. Thus the various magnetic, electric, optical and other properties of—say HCl, should be possible of being expressed in terms of those of H_2 and Cl_2. Now it will appear that if the exact forms of the function ψ were known these determinations could usually be carried out. Examples of the method of procedure, which varies with different cases, will now be given.

(*a*) Let us suppose that a mixture and its isolated constituents are subjected to an electro-magnetic radiation which falls upon them at a certain angle. The radiation will exert pressures on the substances which depend on the reflecting powers of the substances for the particular radiation we are dealing with. Now if the pressures exerted on the constituents were known for various volumes and temperatures, the pressure exerted on the mixture may be calculated. Thus let the equations of state of the isolated constituents a and e under these conditions be given by

$$p_a' = \psi\left(\frac{A_1'M_a}{v}, \ \frac{A_2'M_a}{v}, \ \cdots\right), \tag{22}$$

$$p_e' = \psi\left(\frac{E_1'M_e}{v} \ \ \frac{E_2'M_e}{v}, \ \cdots\right). \tag{23}$$

The functions A_1', A_2', $\cdots$ E_1', E_2', $\cdots$ (which may be given any empirical forms of which the constants are then determined) are determined from values of p_a' corresponding to different volumes and temperatures of the substance, and the values of p_a' are determined from the equation of state of the substance when not subjected to a radiation, and a knowledge of the reflecting powers of the substance under various conditions. Similarly the functions E_1', E_2', $\cdots$ are determined. The equation of state of the mixture is then

given by

$$p' = \psi\left(\frac{A_1'M_a + E_1'M_e}{v}, \quad \frac{A_2'M_a + E_2'M_e}{v}, \quad \cdots\right). \tag{24}$$

Hence the pressure p_r exerted by the radiation on the mixture is

$$p_r = p - p', \tag{25}$$

where p denotes the pressure when no radiation is acting. From this the reflecting and absorbing powers of the mixture under the given conditions may be determined.

At present it is impossible to carry out such calculations through a lack of sufficiently extensive data, and because the exact nature of ψ is not known. But the existence of such relations as indicated may be helpful in predicting various properties of the reflecting power. Thus for example if matter obeyed the gas equation under all conditions it would follow that the reflecting power of a mixture is additive in nature. Since the deviations from the gas laws are due to the existence of the molecular forces of interaction, it follows that the reflecting power of a molecule is affected by the external forces acting upon it.

(*b*) The magnetic permeability of a mixture may be calculated from the permeabilities of the constituents. Thus let the equation of state of the isolated substances a and e in a magnetic field of intensity H be given by equations (22) and (23), where the functions A_1', A_2', $\cdots$ E_1', E_2', $\cdots$ refer to the new conditions. The function ψ remains the same in form since it is independent of the nature of substances, and the application of a magnetic field to a substance might only change somewhat its nature. The functions A_1', A_2', $\cdots$ E_1', E_2', $\cdots$ are determined by the help of the equations

$$\frac{\partial u_a'}{\partial v} = T\frac{\partial p_a'}{\partial T} - p_a', \tag{26}$$

$$\frac{\partial u_e'}{\partial v} = T\frac{\partial p_e'}{\partial T} - p_e', \tag{27}$$

where u_a' and u_e' denote the internal energies at the volume v of the isolated substances a and e when under the action of

the magnetic field. Now

$$u_a' = u_a + \mu_a H^2 v/8\pi, \tag{28}$$

$$u_e' = u_e + \mu_e H^2 v/8\pi, \tag{29}$$

where u_a and u_e denote the internal energies when there is no field acting, and μ_a and μ_e the permeabilities of the substances a and e respectively. Equations (26) and (27) may now be written

$$T\frac{\partial p_a}{\partial T} - p_a + \frac{H^2}{8\pi}\frac{\partial(\mu_a v)}{\partial v} = T\frac{\partial p_a'}{\partial T} - p_a', \tag{30}$$

$$T\frac{\partial p_e}{\partial T} - p_e + \frac{H^2}{8\pi}\frac{\partial(\mu_e v)}{\partial v} = T\frac{\partial p_e'}{\partial T} - p_e', \tag{31}$$

since

$$\frac{\partial u_a}{\partial v} = T\frac{\partial p_a}{\partial T} - p_a, \tag{32}$$

$$\frac{\partial u_e}{\partial v} = T\frac{\partial p_e}{\partial T} - p_e, \tag{33}$$

where p_a and p_e are the pressures of the substances a and e in the absence of the field. On substituting for p_a' and p_e' from equations (22) and (23) in equations (30) and (31) they may be used to determine the functions $A_1', A_2', \cdots E_1', E_2', \cdots$ from values of p_a, p_e, μ_a, and μ_e corresponding to various values of v and T. The equation of state of the mixture under the field H is then given by equation (24). The permeability μ of the mixture is obtained by the help of the equation

$$T\frac{\partial p}{\partial T} - p + \frac{H^2}{8\pi}\frac{\partial(\mu v)}{\partial v} = T\frac{\partial p'}{\partial T} - p' \tag{34}$$

obtained similarly as equations (30) and (31). On multiplying the equation by ∂v and integrating it between the limits v and ∞ it becomes

$$\mu_\infty \cdot \infty - \mu v = \frac{8\pi}{H^2}\int_v^\infty \left\{ T\frac{\partial(p' - p)}{\partial T} - (p' - p) \right\} \partial v, \tag{35}$$

where μ_∞ denotes the permeability at infinite volume. The value of μ_∞ has been shown in Section 6 to be equal to the sum

of the permeabilities of the isolated constituents, and if p' and p are substituted from equations (24) and (5) the permeability μ may be calculated.

In a similar manner the inductivity of a mixture may be calculated from the inductivities of the constituents.

Every property of matter with which a force may be associated can be dealt with along similar lines. Thus for example suppose that a substance is placed in a liquid medium of a given electrical conductivity through which an electrical current is flowing. If the electric conductivity of the substance is not the same as that of the medium certain forces will act upon it. These may be made the basis for calculating the electric conductivity of a mixture in terms of the conductivities of the constituents. Similarly the heat conductivity may be investigated.

The foregoing is only an outline of the uses to which equation (5) may be put; the subject will be further developed in a subsequent paper.

Preliminary Experiments in Obtaining Extremely High Electrical Potentials from Atmospheric Electricity. A. BRASCH, F. LANGE AND C. URBAN. (*Naturwissenschaften*, Feb. 17, '28.) Were it possible to get very high potentials they could be used to produce streams of particles with great velocities that would further the study of atomic disintegration. On account of the technical difficulties in the way of attaining high voltages by using transformers or other electrical apparatus the authors turned to atmospheric electricity following the good example of Benjamin Franklin in his famous Philadelphia experiment. Their experiments were conducted on Monte Generoso near Lugano in the summer of 1927. This mountain was selected because of its accessibility and of the frequency of its thunderstorms.

"The normal electrical field in the atmosphere of the earth, which generally amounts to about 200 volts per meter, is raised during thunderstorms to some hundreds of kilovolts per m. A point only 100 m. above the ground has accordingly a potential from five to thirty million volts above that of the earth. To avail themselves of this the authors swung over a valley a line carrying several hundred square meters of coarse wire gauze provided with points. The line was 760 m. long and the gauze was 80 m. from the ground. The line was protected at each end by a series of insulators. To prevent the formation of the corona with consequent loss of energy thin, round, metallic bodies were strung like beads on the half of the line extending from the gauze to the measuring instruments.

The installation was not ready for operation until the end of August by which time the season for storms had about passed. Fortunately one thunderstorm did, however come. At the height of the storm sparks jumped across a gap 4.5 m. long from a body connected to the suspension line and collecting gauze to an earthed point. The observers believe that the gap could have been greatly lengthened without causing the sparks to cease. They estimate that 1,700,000 volts were obtained by their device. By suspending the gauze at a greater elevation higher potentials can be got. These experiments will be continued in the summer of 1928.

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

INTERNATIONAL ASTRONOMICAL UNION.

THE third general assembly of the International Astronomical Union took place in Leiden, Holland, during the week of July 5 to 13. It was probably the largest gathering of astronomers in history; representatives from 28 different countries were present.

The main work of the Union was performed in sessions of its 28 commissions, each concerned with some particular phase of astronomical or astrophysical science. The Bureau of Standards was represented on the commission for standards of wave-length and tables of solar spectra. The spectroscopy section of this bureau was the first to determine new standards of wave-length both in laboratory arc spectra and in the solar spectrum. These new determinations were directly responsible for the revision and adoption of two sets of international standards of wave-length, one set derived from the iron arc and the other from the sun. Both sets are based on the primary cadmium or equivalent neon standard and the individual values are now believed to be correct to 1 part in 4 or 5 millions. Each system of standards covers approximately an octave of the spectrum, ultra-violet to red. The system of laboratory standards consists of wave-lengths corresponding to about 300 bright lines in the emission spectrum of the iron arc and the solar standards are represented by wave-lengths corresponding to about 400 dark lines in the absorption spectrum of the sun. The iron standards replace a similar system which has been in international use for about a decade but which was recently found to contain systematic errors of the order of magnitude of 1 part in 1 million. The solar standards will replace the values determined by Professor Rowland about 40 years ago.

In addition to adopting these revised standards the International Astronomical Union advised the investigation of vacuum arc and furnace spectra to determine if their use

* Communicated by the Director.

will permit further improvement in laboratory standards of wave-length and recommended the extension of the tables of standards to longer and to shorter waves, placing special emphasis on the importance of better standards among the very short waves.

SCIENTIFIC BY-PRODUCT OF LEVULOSE INVESTIGATION.

THE research on the identification of the unknown constituents of hydrolyzed inulin has resulted in the isolation and description of one well defined crystalline substance.

Inulin, the starch-like substance found in the juice of dahlia tubers, may be converted by hydrolysis or treatment with acid into the sugar known as levulose or fructose. It was discovered that but 92 per cent of the expected amount of fructose was obtained by this hydrolysis. Since it seems probable that fructose will take its place as a large-scale commodity it was important to learn the nature of so large an impurity in hydrolyzed inulin. By removing the fructose by precipitation with lime a residual sirup was obtained which instead of rotating polarized light 91 degrees to the left as does fructose, rotated 55 degrees to the right. This sirup proved to be a mixture of sugars none of which could be isolated.

By treatment with very strong acid at boiling temperature a partial hydrolysis was effected and it was found that the sole product of hydrolysis was fructose.

The mixture of sugars was then converted to their acetates and from the mixture one acetylated sugar crystallized and was purified and analyzed. This was then converted back to the original sugar which was finally obtained in crystalline form. This sugar, which has never hitherto been isolated, proved to be a disaccharide composed of two molecules of fructose combined to form a compound sugar rotating polarized light to the right. It is conjectured that it is an integral part of the inulin molecule and will ultimately assist in the determination of the structure of inulin.

LINEAR THERMAL EXPANSION OF AMBER.

THE linear thermal expansion of a sample of amber purchased from the National Importing Company, Inc., of

New York City, was investigated by this bureau, over various temperature ranges between 0 and 90° C. The results obtained are given in the following table:

Temperature range ° C.	Average coefficient of expansion per degree Centigrade.
0 to 15	0.000047
0 to 30	0.000050
0 to 50	.000053
0 to 90	.000061
15 to 30	.000053
30 to 50	.000058
50 to 90	.000072

Between 0 and 50° C. the coefficient of expansion of this sample of amber is about five times the coefficient of ordinary steel.

HEALTH HAZARDS IN CHROMIUM PLATING.

A PAPER on health hazards in chromium plating, by J. J. Bloomfield, of the Public Health Service, and W. Blum, of the Bureau of Standards, was presented at the meeting of the American Chemical Society at Evanston, Ill., on August 9. This paper has now been published in "Public Health Reports" for September 7, 1928, and reprints may be obtained from either the U. S. Public Health Service or the Bureau of Standards, Washington, D. C. A brief resume of this paper is as follows:

During the past few years chromium plating has developed rapidly, and it is now being extensively applied upon automobiles and plumbing fixtures because of its high luster and resistance to tarnish; and upon printing plates, gages, tools and dies on account of its extreme hardness. The bath used for chromium plating consists principally of chromic acid. During the plating process considerable hydrogen and oxygen are liberated, and these carry a spray of chromic acid into the air.

It has long been known that in the manufacture of chromic acid and chromates, the operators are subject to attack and perforation of the nasal septum; and to the formation of ulcers or "chrome holes" upon the hands or other exposed parts of the body. Accordingly some provisions have been made in all chromium plating plants for artificial ventilation

and for other sanitary measures. In spite of these precautions, however, the employees in some plants have been affected in the above mentioned ways.

In order therefore to determine the extent of the hazard and the best means of overcoming it, a survey was conducted in several commercial plants. This included a study of the methods and degree of ventilation of the concentrations of chromic acid in the air breathed by the workers, and a physical examination of the latter. Although only six plants were visited, and twenty-three persons examined, the results were so consistent in different plants, and agreed so well with previous experience with chromates, that certain tentative conclusions and recommendations are warranted.

It was found that exposure to very low concentrations of chromic acid, e.g., one milligram in 10 cubic meters, or one-sixtieth of a grain in 350 cu. ft. (which is about the volume of air breathed by a worker in eight hours), is sufficient to cause nose bleed and nasal inflammation in a week or less. Higher concentrations or longer exposures cause extensive attack and even complete perforation of the nasal septum. This is painless, however, and the operator may be entirely unaware of the perforation. Many of the employees were found to have chromium ulcers on the hands or other exposed parts of the body. No evidence was found of injury to the respiratory tract except in the nose, nor of any effect upon the digestive system or the kidneys.

While therefore there is a real hazard in chromium plating, it is not critical, and can be entirely eliminated by suitable measures. These should include an effective system of ventilation in which the air is drawn horizontally across the plating tanks into a narrow duct in which the air velocity should be about 2,000 feet per minute. So far as possible rubber gloves, aprons and shoes should be worn. Frequent applications of vaseline or mentholatum salve to the nose and hands greatly reduce the danger or ulceration. All cuts and abrasions of the skin should receive regular inspection and medical treatment.

If these simple, entirely practicable measures are taken, the hazard can be practically eliminated. There is no reason therefore to fear any serious injuries from the extension of chromium plating that is likely to occur in the next few years.

WORKABILITY OF PORTLAND CEMENT PASTES.

THREE methods of tests for workability of cement pastes—the extrusion cylinder, the ball plasticimeter, and the capillary tube—were discussed in Technical News Bulletin No. 132 (April, 1928). A fourth method, using the MacMichael viscometer with its modified "paddle" has been studied. This instrument was too small to permit the study of dry mortars. However, a summary of the results already obtained develops two items of interest. First, a comparison was made between the workability of the cements, when tested as neat pastes, as shown by the MacMichael instrument and also as shown by the three methods of test referred to above, which were also reported in the paper published in the *Proceedings of the American Concrete Institute*, "Cement As A Factor In The Workability Of Concrete," Vol. XXIV, 1928, pp. 43–55. There was quite good agreement, in this respect, between the MacMichael instrument and the capillary tube reported in the earlier paper. Secondly, at least within the scope of the instrument used, the relative results of a number of cements tested as neat cement pastes, or in a mortar of a certain proportion, may not be the same as the relative results obtained when testing the same cements in a mortar of different proportions.

TENSILE STRENGTH OF MORTAR IN BRICKWORK.

A SERIES of tests of the adhesion of mortar to sand-lime brick has furnished an opportunity for comparing the tensile strength of the mortar in the brick with the strength of the same mortar in the form of standard briquets. The results herein reported were obtained with a 1 : 1 : 6 cement-lime mortar, in which various amounts of diatomaceous earth had been substituted for equal amounts of lime. The mortars were mixed to a consistency which gave a ½ inch slump in a 2 x 4 inch cylinder. From each batch of mortar, six standard tensile briquets were cast and ten pairs of brick joined together.

The bricks and briquets were aged together in the air of the laboratory for 28 days, after which the tensile strength of the mortar and the adhesion of the mortar to the brick

were determined. The mortar was then removed from the brick to which it adhered, separating readily in slabs about 0.45 inch in thickness. The slabs were cut into specimens about 3 x 1½ inches, care being taken to obtain specimens both from the interior and the edge of the slab.

Saw cuts, ¼ inch deep, were made at the midpoint on each side of the specimens cut from the interior of the slabs, to form a reduced section, one inch across, for the tensile tests. With the specimens cut from the edge of the slab, a single cut only was made from the side opposite the exposed edge, so that this edge might be included in the reduced section being tested.

Strips of light wood placed over two layers of blotting paper were clamped to each end of the specimen. These formed grips by means of which the upper end of the specimen could be attached to a support, and a container for shot attached to the lower end. Shot was poured slowly into the container until the specimen failed. The container was then weighed, and by calculation, the tensile strength of the mortar in pounds per square inch was obtained.

The results are given in the accompanying table. The nature of the slabs from which the specimens were cut was such that equal numbers of specimens could not be obtained from each mortar. In the table, tensile strengths are the average of the number of tests given in the adjoining column except those of the briquets where the figures in all cases were the average of six tests.

It will be noted that in ten of the eleven mixes tested the specimens from the edge of the mortar as it lay in the joint were stronger than those obtained from the interior portion of the joint. Also in eight of the eleven mixes the mortar specimens, both from the edge and the interior, were stronger than the same mortar in briquet form. There are several factors which may affect the strength of the mortar in masonry so that its strength is not necessarily related to that in briquet form. Tapping and jarring as the brick are laid, pointing up the edges, and the absorption of the brick all tend to produce a denser mortar. The interior of mortar in brickwork may be kept in a damp condition longer than the mortar in briquet form, thus tending to increase the strength of a

cement mortar. The surface exposure is relatively less in the masonry joint than in the briquet, and consequently carbonation from the air is less. In the particular mortars tested the factors tending to increase the strength were apparently more effective than the others. Whether this would be true of all mortars cannot be predicted from the available data.

TENSILE STRENGTH OF MORTAR IN BRICK.

Diatomaceous Earth Substituted for Lime.	Specimens from Edge.		Specimens from Interior.		Tensile Strength of Mortar in Briquets (Average of 6 Tests).
	Number of Specimens Tested.	Tensile Strength, Average.	Number of Specimens Tested.	Tensile Strength, Average.	
Per Cent.		Lbs./In.^{2}		Lbs./In.^{2}	Lbs./In.^{2}
0	6	41	3	45	53
10	8	53	5	46	59
20	7	69	5	61	51
30	8	56	5	34	53
40	9	75	8	65	59
50	9	73	7	53	43
60	6	82	13	58	54
70	14	70	10	52	40
80	14	80	10	69	41
90	15	73	9	67	27
100	15	65	10	52	36

SAGGER INVESTIGATION.

TECHNICAL News Bulletin No. 130 (February, 1928) gave a summary of the method of procedure being followed for developing sagger bodies according to fundamental properties.

The thermal expansion, moduli of elasticity and rupture at room and elevated temperatures have since been determined with a view of establishing the value of the "resistance to thermal shock factor *R*" (described in Technical News Bulletin No. 120, April, 1927), which would give an indication of the probable life of a particular sagger body. At this writing the data, obtained on the fired sagger bodies, show that the resistance factor "*R*" gives a fairly good indication as to the life of the sagger, when subjected to repeated thermal shock, if referred to a group of bodies containing only fine grog or a group containing only coarse grog. It does not appear to apply when comparing the life of a coarse-grogged sagger with that of a fine-grogged sagger. This would indicate that

the stresses set up in the fine-grogged body are of a different type than those in the coarse-grogged body.

It was also found that (1) saggers containing only a porous grog showed greater resistance to thermal shock than those containing a partially vitrified grog; (2) the rate of thermal expansion of the fine bodies was higher than that of the coarse bodies in 67 per cent. of the observations, similar in 20 per cent., and lower in 13 per cent.; (3) a comparison of the thermal expansion of the sagger bodies with that of the two clays composing each of the bodies shows that in 12 out of the 15 instances the combination was advantageously made with respect to either one or both clays.

Sagger bodies similar to the above have been prepared, but have been fired approximately 50° C. higher. These will be tested and the results compared with those obtained on bodies burned at the lower temperature.

RUBBER BINDERS FOR FOUNDRY CORE.

Sand cores used in the foundry industry have played a very important part in the development of the art of molding and in the reduction of molding costs. There still remain, however, some phases of present day foundry core practice that may be improved upon.

Cores as generally used in the foundry, at the present time, owe their strength or coherence to their content of artificial bonding material and to the baking treatment which is given the core. Strength, however, is required only before casting and easy disintegration of the sand core is very desirable after the cast metal has solidified around it.

The removal of cores from the casting is an expensive, laborious and dusty task, often requiring the use of a pneumatic chisel or other tools. Cracked castings, due to hard cores, which do not crush as the metal solidifies and core blows, due to low permeability of the cores are sources of loss to foundries.

Recently there has been developed, at the bureau, a new foundry core sand binder, rubber or some allied material being used as the basis of the core binder. The outstanding advantages are:

1. The cores crush readily, falling to loose sand of their own accord so that the core sand may be poured from the casting instead of having to be dug out.

2. The cores have greater strength than a green sand core and extend the range of jobs to which a readily crushed core may be applied.

3. The cores are not oven baked; they are merely air-dried.

4. The cores are of high permeability and show remarkable freedom from blowing.

The new rubber core binder consists essentially of a solution of unvulcanized rubber in gasoline. The amount and type of rubber binder used in making cores depend upon the type of core sand, the size of core, and the metal to be cast around it. A core-strength equivalent to that of a green sand core or baked oil sand cores can be attained by the use of the rubber binders. The new binders have proved to be successful in producing sand cores for castings of lead, tin, zinc, brass, phos-bronze, bronze, aluminum, iron and steel.

These new rubber types of binders are discussed in considerable detail in our Letter Circular No. 252, Rubber Binders for Foundry Cores, which is now ready for distribution. Address inquiries only to the Bureau of Standards.

RAYON PROJECT.

THE work on rayon at the bureau has centered chiefly on the study of the effect of moisture on the strength and elongation properties. Actual work along these lines was delayed pending the development of adequate testing procedure and the design and standardization of the necessary equipment.

The method for obtaining stress-strain curves, using a multiple-strand specimen, has been refined considerably. In developing this method yarns of other textile fibers, besides rayon, were studied for comparison. The data obtained are being collated for publication.

This multiple strand strength method consists essentially of winding the yarn under controlled uniform tension onto a specimen holder which in turn may be placed in the jaws of the testing machine without further handling.

It has been demonstrated that the method is simple in

operation, gives accurate and reproducible results, and is sufficiently sensitive for the purposes of the main study.

Using this method, comparative results are being obtained on all four types; viscose, cuprammonium, nitrocellulose, and cellulose acetate. Different relative humidities are being used which will indicate what effect the moisture has on strength and stretch.

For the wet tests a device has been designed and built which consists of a tank built around the lower jaw of a Scott tester. This tank is equipped with heaters and temperature control. This equipment permits the specimen to be immersed in water for definite periods of time and under controlled temperature. It is then broken without further manipulation. It has the advantage that the yarn is not handled from the time it is inserted in the jaw until the test is completed.

Some supplementary work is being done on the cellulose acetate type of rayon to determine what takes place when the rayon is boiled in water. It is recognized that a delustering action results and that the properties of the rayon are effected in various ways. The results have indicated that little, if any, regeneration of the cellulose acetate to cellulose takes place as has been advocated in some theories.

Some preliminary work was done to determine the effect of high pressure and of cathode ray exposures on rayon. This showed little promise and was not continued.

NOTES FROM RESEARCH LABORATORY, INCANDESCENT LAMP DEPARTMENT OF THE GENERAL ELECTRIC COMPANY.*

TEMPERATURE AND BRIGHTNESS OF THE NEW STANDARD TYPE OF INCANDESCENT LAMPS.

By W. E. Forsythe and E. M. Watson.

[ABSTRACT.]

THE new standard type of Mazda lamp, which has as its most distinctive feature an inside-frosted bulb, is the result of a successful endeavor to improve the construction of incandescent lamps over the range of ratings that is suitable for domestic lighting and services of like caliber. To satisfy all the demands of good lighting it was found necessary to have six different sized lamps in this new type, that is, 15 watt, 25 watt, 40 watt, 50 watt, 60 watt, and 100 watt.

A number of improvements were made on the lamps during the process of simplification, so that it was possible to make the new type markedly better than the lamps they were intended to replace. The improvement that gave the new type of lamps their distinctive appearance was the method of frosting the bulb on the inside.

Among the other improvements may be mentioned a reduction of bulb size and the coiling of the filament. This last improvement made it possible to reduce the number of supports and still keep the filament in place.

A lamp bulb frosted on the outside by either the sand blasting or the acid etching process absorbs between five to ten per cent. of the light. A 5 per cent. loss of light does not seem high, but it is too high when an effort is being made to produce the best possible light source consistent with practical operation. Frosting the bulbs by the new process on the inside was found to increase their absorption by less than 1 per cent. above that of clear bulbs of the same size and shape.

* Communicated by the Director

The main reason, of course, for frosting the bulb of the lamp is to reduce the brightness of the source, because the tungsten filament in the lamp is operated at such a very high temperature that it makes a very bright source if viewed directly. The brightest point on a number of these inside frosted lamps has been measured, and the results are given in Table I, where the brightnesses of some other standard sources are included for purposes of comparison. In this table also is given the brightness of the filament of the lamp as it would be observed if it were mounted in a clear bulb. It will be noted that the density of frosting adopted by the engineers is such as to reduce the maximum brightness observed by about a factor of fifty. Quite a number of filaments, such as are used in these new lamps, of different wattages were mounted in clear bulbs and their temperatures measured. These values together with the efficiencies of the lamps are also given in Table I.

Brightness of Filaments and Bulbs of Standard Line Lamps and Some Other Sources for Comparison.

Lamp.	Volts.	Watts.	Type.	L/W.	Maximum Temp. °K.	Color Temp. °K.	Maximum Bulb Brightness cand./cm.²	Filament Bright. c./cm.²
Kerosene flame flat wick						1920		1.2
4-watt per candle carbon lamp						2080		55.0
40-watt tungsten straight filament			vacuum			2500		206.0
40-watt tungsten (frosted bulb)			vacuum				2.5	
Sun as observed at earth's surface								165,000.0
Clear sky, average								0.4
Standard type lamp	115	15	vacuum	8.6	2475		4.0	214.0
" " "	115	25	"	9.5	2510		4.5	245.0
" " "	115	40	"	10.2	2545		5.5	278.0
" " "	115	50	gas-filled	10.5	2660		9.0	430.0
" " "	115	60	"	11.3	2695		9.5	490.0
" " "	115	100	"	13.4	2755		12.5	600.0

VISIBLE RADIATION CHARACTERISTICS OF INCANDESCENT OXIDES.

By Marcella Lindeman Phillips.

INVESTIGATION of the visible radiation of certain oxides, with reference to their possible use as illuminants, has extended over a period of more than a century, but few quantitative results have been published.

This work is an investigation of the visible radiation characteristics of various oxides and oxide mixtures when heated by cathode ray bombardment, gas-air and oxy-gas flames, to brightness temperatures ($\lambda = 0.665\ \mu$) from about 1400 to 2000° K. Ordinary gas-air burners, equipped with valves regulating the gas pressures, were used in flame heating. The oxides were kept in the oxidizing part of the flame. A cold cathode discharge tube, connected through a long capillary to an oxygen tank, was used in studying the oxides under cathode ray bombardment. The oxide, mounted in a nickel button, served as the anode, and was viewed through a window at the end of a long arm of the tube. With the window thus at some distance from the hot circle the error due to blackening of the tube during operation was greatly reduced.

The oxides investigated were urania, ceria, lanthana, neodymia, erbia, yttria, zirconia, thoria, alumina, beryllia, magnesia, and mixtures of thoria with one per cent. ceria (the Welsbach mantle mixture), one per cent. and less of urania, one per cent. neodymia, and one per cent. manganese oxide.

An optical pyrometric method of observation was used, measurements of the brightness of the oxide under test being made with a disappearing filament type of pyrometer, equipped successively with red (effective $\lambda = 0.665\ \mu$) and blue (effective $\lambda = 0.467\ \mu$) screens, from which the red brightness temperature and the ratio of red to blue intensity ratio were determined, and with a combination of red and green screens having an effective wave-length approximately equal to the Crova wave-length, from which the candles emitted per square centimeter of surface were determined.

The oxides used, unless otherwise stated, were in as pure a state as could be obtained, and were either pressed as compactly as possible in a hydraulic press, or fused to insure a

smooth surface. The samples of the fused oxides were prepared by melting them in an atomic hydrogen arc by C. W. Hewlett of the General Electric Company Laboratory in Schenectady. Due to the fragility of the pressed oxides, fused oxides were used when possible.

In general, linear relations were found between the logarithm of the red-blue intensity ratio and the reciprocal of the brightness temperature, and between the logarithm of the candles emitted per unit surface area and the logarithm of the brightness temperature. Different modes of heating gave different radiation curves for the same oxide.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

McBAIN-BAKR BALANCE FOR SORPTION OF VAPORS BY FIBROUS AND FILM MATERIALS.[1]

By P. T. Newsome.

A SHORT description with a diagram of an apparatus for the rapid determination of the sorption of vapors by fibrous and film materials. The essential feature is the use of a McBain-Bakr quartz fiber spring balance.

THE DEPENDENCE OF THE RESOLVING POWER OF A PHOTOGRAPHIC MATERIAL ON THE WAVE-LENGTH OF LIGHT.[2]

By O. Sandvik and G. Silberstein.

THE resolving powers of six various emulsions have been investigated. The spectral region covered extends from wave-length 380 $m\mu$ towards the red end of the spectrum as far as the sensitivity of the particular emulsion would permit. The resolving power has a maximum value at a wave-length of 380 $m\mu$, decreasing rapidly in the blue-green to a minimum value at about a wave-length 535 $m\mu$.

It is interesting to note that the change in resolving power with the wave-length corresponds approximately with the change in the absorption coefficient with the wave-length in the spectral region investigated.

* Communicated by the Director.

[1] Communication No. 343 from the Kodak Research Laboratories and published in *Ind. Eng. Chem.* **20**: *827. 1928; Sci. Ind. Phot.* **8A**: *95. 1928.*

[2] Communication No. 344 from the Kodak Research Laboratories and published in *J. Opt. Soc. Amer.* **17**: *107. 1928.*

The Rehabilitation of the Mines in Northern France. L. LAHOUSSAY. (*La Nature*, May 15, '28.) France in 1913 used 65,000,000 tons of fuel of which 24,000,000. were imported. The two departments of Nord and Pas de Calais produced two-thirds of all the coal mined in France and employed 130,000 workers for that purpose. Unfortunately these departments were soon invaded. Even as early as August, 1914, the Anzin mines were lost and by the end of the year two-thirds of this northern coal region was in the hands of the Germans. The lines of battle swayed back and forth over the coal fields of the value of which both sides were fully aware. The Germans had no desire to leave the mines in workable condition and no later than 1915 blew up the casings of pits at Lens and Liévin. Additional destruction was accomplished in 1917. A year later they took up the task systematically but had not completed it before they were driven out. The usual procedure was to attach a charge of explosive to the end of a beam just about equal in length to the diameter of the shaft. The beam was lowered and manipulated so that the charge was held between one end of it and the casing. After the explosion had pierced the casing water poured in from adjacent strata and drowned the mine. Of 212 mines in the possession of the Germans 140 were blown up, though not always with the results desired.

In April, 1919, a survey of the situation showed that 92,600,000 cu. m., or that number of tons, of water had to be removed from the mines. The greater part of this water was situated at depths ranging from 200 to 400 meters, though some of it was 700 or 800 m. below the surface of the earth. The pumping of this water from intercommunicating mines and its discharge into canals in a country as flat as Flanders presented many problems for solution. Different methods of pumping were used for different levels, and the work of restoring the shafts was undertaken with full recognition of the attendant difficulties. To furnish electric current for the operations it became necessary to erect a central station of 18,000 kw. capacity.

The removal of the water began in 1920 and was at its height in 1921. The mines when finally freed from water had been unworked for periods varying from 5 to 12 years. Their timbers were rotten and their metal parts corroded. In spite of all these drawbacks the production of coal was soon resumed and each succeeding year sees it increasing. In 1919 only one per cent. of the pre-war quantity was mined but by 1920 it had become 4 per cent. and in 1927 110 per cent. To any one who saw the mines shortly after the war their rehabilitation in so brief a time must appear as a triumph of the engineers of France. G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY AND SOILS.*

AVOCADO OIL.[1]

By G. S. Jamieson, W. F. Baughman, and R. M. Hann.

[ABSTRACT.]

THE fatty oil contained in the pulp of the avocado was investigated. The chemical and physical characteristics were determined. The oil gave an iodine number of 94.4 and a saponification value of 192.6, and the composition was found to be as follows:

Glycerides of:	Per cent.
Oleic acid	77.3
Linolic acid	10.8
Myristic acid	trace
Palmitic acid	6.9
Stearic acid	0.6
Arachidic acid	trace
Unsaponifiable matter	1.6

Experiments showed that the oil could probably be used for the manufacture of hard soap. When expressed from sound fruit that has been partly dehydrated, the oil could be used locally as an edible oil or a cooking oil.

THE CHEMISTRY OF LIGNIN.

II. FRACTIONAL EXTRACTION OF LIGNIN FROM CORN COBS.[1]

By Max Phillips.

[ABSTRACT.]

LIGNIN was fractionally extracted from corn cobs by a 2 per cent. alcoholic sodium hydroxide solution at room temperature, by 2 per cent. aqueous sodium hydroxide at 100° and 135°, and finally by 4 per cent. aqueous sodium hydroxide

* Communicated by the Chief of the Bureau.

[1] Published in *J. of the Oil and Fat Industries*, 5: 202–206, July, 1928.

[1] Published in *J. of American Chemical Society*, 50: 1986–1989, July, 1928.

at 180°. Each method of extraction was continued until no further lignin was obtained, before the next method in the series was employed. The results justify the conclusion that the lignin in corn cobs is unequally combined with the carbohydrates, part of it being loosely bound, possibly in the form of an ester, and the remainder being more firmly held, probably in the form of an ether-like combination.

NOTES FROM UNITED STATES BUREAU OF MINES.*

RECOVERY OF FINE GOLD BY AMALGAMATION.

THE frequency of cases of poor recovery of fine gold by the amalgamation process has led the United States Bureau of Mines, Department of Commerce, to publish an information circular on the subject.

Experience has shown that in many cases error has been made because the true gold content of a particular sample or deposit was not known. Fire assays of representative samples give accurate results and should be considered final in determining the gold content.

The best method for recovering gold depends on the form of its occurrence in the material to be handled. An experienced operator can obtain a good idea of the amount of free gold and can tell something as to the fineness of it by careful panning. The sulphides should be separated and cleaned from the free gold and gangue, and then weighed and assayed. If the sulphide carries gold, it is probable that part of the gold in the slimed portion is locked up with sulphides and will not amalgamate.

It is advisable, if practicable, to have an expert make a microscopic examination and report on minerals present and how associated in the gangue. Such an examination is needed by the examining mining engineer or metallurgist before he can recommend methods of recovery.

The fine gold lost in the usual amalgamation process is often called "float gold." Most of this gold is probably in the form of thin laminæ, flattened grains, or scales, and its loss is due to noncontact with the mercury. A thinner pulp, provided by the introduction of swinging amalgamated plates as obstructions in the pulp flow and the stirring action caused by more frequent drops onto the different sections of the amalgamation plates has improved the recovery of such gold. Fine gold is readily recoverable by good contact with the

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amalgamation plates and should not be confused with the gold included in fine sulphides or in other nonamalgamating forms.

"Rusty gold" is a term that has been adopted to designate gold which, though apparently free, does not readily amalgamate. It is known that a thin film of sulphur, oxide of iron, silica, grease or other substances may cover the surface of the gold particle and prevent amalgamation. The film is usually attacked by grinding or some form of abrasion and by the use of alkalies or other chemicals to dissolve the grease.

The fine gold which is contained in pyrite does not readily unite with mercury. This gold is mostly recovered with the pyrite concentrate or leached by cyanidation. Tellurides do not give up the contained gold to direct amalgamation. The roasting of pyrite and tellurides improves the condition for amalgamating the gold but does not insure a high recovery.

Silver-plated copper plates are generally used to recover the free gold from ore by amalgamation processes. For best results the plates must be kept as clean as possible. Mercury is worked into the surface of the plates until there is exposed a bright pasty amalgam that readily retains the gold as the ore pulp flows over the surface. To effect amalgamation each particle of gold must come into contact with the mercury; the attempt is made to accomplish this by passing the crushed ore and water in a thin layer over the entire surface of the plates and providing for a drop from each of the plates in the series.

Good amalgamation conditions are easily reversed by the careless introduction of oils and grease. Soluble sulphides in the ore will darken the mercury and lower the gold recovery. Arsenic and antimony are particularly harmful. Many of the base metals unite with the mercury to form base bullion, or, even worse, cause the mercury to slough off and carry away precious metals.

Placer gold refers to that gold obtained from alluvial deposits which may have been formed by stream, river, or by the action of water along beaches, and usually includes all gold-bearing loose sand or gravel. The recovery of placer gold is usually made by drift mining on bed rock, hydraulic mining, or dredging.

Since its introduction, the cyanide method of recovering

fine gold from silicious ores has been the usual method employed for the recovery of gold lost in amalgamation processes. In many recently established plants, cyanidation has entirely supplanted amalgamation for the recovery of fine gold.

Before expending any considerable time or money in attempting gold recovery, each prospect should be examined and approved by a competent operator familiar with the particular class of mining necessary, or by a competent mining engineer and metallurgist.

LARGE QUANTITIES OF SURPLUS MILITARY EXPLOSIVES USED INDUSTRIALLY.

MORE than 126,000,000 pounds of TNT and other surplus military explosives accumulated by the Government at the close of the World War have been used for industrial purposes, states Dr. Charles E. Munroe, Chief of the Explosives Division, United States Bureau of Mines, Department of Commerce. These explosives have been expended in road building, in construction of dams and reservoirs, in draining swamps, in clearing cut-over lands, and for other useful purposes which have added materially to the wealth of the Nation.

After the entrance of the United States into the World War, the Nation set about the production of military explosives on a scale never before undertaken, and this work continued with such acceleration that when the Armistice was declared the country was producing military explosives in quantities never before realized. There is little doubt, Dr. Munroe points out, that this developed capacity was a material factor in ending the War.

A consequence, however, was the accumulation at various points in this country of enormous stocks of explosives, whose safeguarding during storage and transportation constituted a serious and costing obligation, while entailing a menace to the communities near which the material was stored.

The Bureau of Mines, which had taken an active part in the technical research necessary to the production of military explosives on a tremendous scale, advocated the use of these great stocks of surplus explosives on governmental and industrial peace-time projects, pointing out the heavy expense that would be entailed for either the continued preservation

or the destruction of these explosives. This suggestion met with much adverse criticism, great stress being laid on the fact that military explosives, and particularly, TNT never had been used industrially and were, therefore, unfit for such purposes. The Bureau, however proceeded to demonstrate the suitability of these explosives for industrial purposes and issued several publications setting forth the results it had obtained in practice in the field and giving detailed instructions as to the best methods of use. The result was that this huge store of military explosives, instead of being a total loss or constituting a menace to public safety, was diverted into useful peace-time purposes.

Recently the Bureau was informed that some 250 tons of this military TNT, stored for use near an important Federal project, had deteriorated into a dangerous condition and should be destroyed. An explosive expert was detailed to inspect this supply. When tested, both at the Bureau of Mines Experiment Station at Pittsburgh, and at Picatinny Arsenal, this suspected TNT was found to conform completely with the specifications under which it was originally purchased and to be in a perfectly stable condition. This TNT had been packed loose in wooden boxes and with time some of these boxes had become warped and broken, making it necessary to repack such material if it is to be offered as freight.

The expert who examined this TNT reported that it was in first class condition and entirely suitable for use as a blasting agent. It is gratifying, concludes Dr. Munroe, to find that TNT, which has disclosed such admirable qualities for use in blasting, has now been shown, from this test of storage for upwards of ten years, to have excellent keeping qualities also.

CARBON MONOXIDE FROM AN AUTOMOBILE ENGINE USING ETHYL GASOLINE.

PUBLIC interest in atmospheric pollution by automobile exhaust gas, particularly with respect to the ventilation of vehicular tunnels, makes it desirable to ascertain whether the use of modern automobile fuels is tending to change the amount and composition of the products of combustion. The

Bureau of Mines, in coöperation with the Ethyl Gasoline Corporation, has completed tests to determine whether any significant difference exists in the carbon monoxide content of the exhaust gas emitted by an automobile engine when its fuel is changed from ordinary gasoline to the same gasoline containing ethyl fluid (the active ingredient of which is tetraethyl lead) all other operating conditions remaining the same. The results of these tests, which included carburetor adjustments ranging from "rich" to "lean" with engine operating at three-quarter to full load, show no significant change in the composition of the exhaust gas upon changing the fuel supply from ordinary gasoline to the same gasoline containing tetraethyl lead. This was true for tests in which detonation or "knock" was evident as well as for tests in which no detonation was audible. Also, no significant difference in the amount of carbon monoxide per horse power was noted. From a practical health and safety standpoint the amounts of carbon monoxide produced at a given condition of operation were the same regardless of the fuel used.

INERTS IN COAL.

An investigation has just been started at the United States Bureau of Mines Pittsburgh Experiment Station on the effect of inerts in coal on its utilization. This work, which is being done in coöperation with the Carnegie Institute of Technology and the Pittsburgh Coal Company, will deal primarily with the effect of "fusain" or mineral charcoal on coking properties of coal and with the effect of ash constituents on clinker formation. Several mines of the Pittsburgh bed have been sampled and the coal benches are being analyzed separately for distribution of inert matter. Coking properties of the various benches will be determined and the softening points of the ashes as well.

USE OF MEGGER CIRCUIT IN GEOPHYSICAL PROSPECTING.

The increasing interest in the use of electrical or other geophysical methods for the location of underground ore deposits has led the United States Bureau of Mines, to study the possibilities of the use of the megger circuit for the measure-

ment of the variation of ground resistivity, an important factor in this means of mineral prospecting.

The megger may be used to measure the various average resistivities at different depths from the surface or to compare the various average resistivities at the same depths. With its use it is possible to locate the direction of the dip and strike of a concealed intrusion, such as a body of ore. About three sites or areas can be measured in one day to a depth of 600 ft., by a crew of three men.

The megger as it is built at present is not entirely suited for geophysical prospecting, states Dr. F. W. Lee, in Technical Paper 440, just issued by the Bureau of Mines. Various improvements which would help in the operation of this instrument in the locating of underground ore bodies are summarized in Technical Paper 440.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, September 12, 1928.*)

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Dr. Robert M. Cole, Chemist, American Dyewood Company, Chester, Pa.

Mr. C. Laurence Warwick, Secretary-Treasurer, American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa.

NON-RESIDENT.

Mr. Benjamin Franklin Affleck, President, Universal Portland Cement Company, 208 South LaSalle Street, Chicago, Illinois.

Mr. Charles C. Brush, Naval Architect and Marine Engineer, Bureau of Lighthouses, Washington, D. C. For mailing: Box 161, Route 10, Bethesda, Md.

Mr. L. J. Buttolph, Electrical Engineer, 410 Eighth Street, Hoboken, N. J.

Dr. Clinton J. Davisson, Physicist, Bell Telephone Laboratories, Inc., 463 West Street, New York City.

Mr. Percy Tate Griffith, Rye, N. Y.

Mr. R. J. Wensley, Electrical Engineer, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

STUDENT.

Mr. William A. Kearney, Student, 4926 Garden Street, Bridesburg, Phila., Pa.

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Dr. Theodore K. Cleveland, 432 South Fifty-fourth Street, Philadelphia, Pa.

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Mr. Benjamin Wiley Sands, 456 "K" Street, N.W., Washington, D. C.
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Mr. Ralph C. Stewart, First National Bank Building, 1500 Walnut Street, Philadelphia, Pa.
Mr. John P. Sykes, Baldwin Locomotive Works, Paschall Station, Philadelphia, Pa.
Mr. C. C. Vogt, Armstrong Cork Company, Research Division, Lancaster, Pa.
Mr. Francis R. Wadleigh, Consulting Fuels Engineer, Consolidated Gas Company of New York, 4 Irving Place, New York City.
Mr. S. D. Warriner, 1421 Chestnut Street, Philadelphia, Pa.
Mr. John E. Zimmermann, Day and Zimmermann, Inc., 112 North Broad Street, Philadelphia, Pa.

LIBRARY NOTES.

RECENT ADDITIONS.

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AUERBACH, FELIX. Modern Magnetics. No date.
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BOOK REVIEWS.

TECHNICAL DRAWING, a manual for evening classes and junior technical schools. By George Edwin Draycott, Wh.Ex., A.M.I.Mech.E. Head of the Mechanical Engineering Department, Borough Polytechnic Institute, London. viii–232 pages (18 x 11 cm.), cloth. New York, Oxford University Press, American Branch, 1927. Price, $2.

There is no branch of manufacture or construction which does not require for its efficient prosecution men, and often a large corps of men, with varying degrees of technical qualification, who are acquainted with approved methods of depicting the objects to be produced or erected, their details, supplying their dimensions and all other information which is required by the workman in the shop or in the

field. There is much for the student to learn in the principles of draftsmanship, the methods of descriptive geometry, upon which technical drawing is based, a degree of manual dexterity and the technique of arranging the plans depicted in accordance with adopted practice as well as an irreducible minimum of previous training in elementary mathematics and a more or less diversified practical knowledge. These requirements relate to the achievement of draftsmanship, only, apart from purely technical qualification which is often, and in fact generally, expected of the modern draftsman.

Technical schools of university grade include more or less elaborate courses in drawing in their curricula, but many of the draftsman who occupy positions in the ranks of the calling are recruited from evening and vocational schools which have come into existance in modern times. "Technical Drawing" is addressed to the latter class. Its purpose, the author states, is to provide a method of instruction which has been found satisfactory in actual practice over a long term of years. The usual topics are covered; instruments and materials, scales, geometrical construction, projections, intersections and developments, sketching, isometric drawings and the technique of lettering, dimensioning and shading drawings.

The making of technical drawings is not a deductive art, and no matter how well versed in the principles of descriptive geometry and geometrical construction the student may be, he will not achieve proficiency without contact with the methods of professional practice and illustrations, which are lacking in this book; professional drawings executed in the best possible manner are necessary for the student to acquire an acquaintance with what he will be expected to produce in the engineering drawing office. There is much of value and practical utility in the book, but as representative of approved practice both in descriptive matter and quality of illustrative example, it falls far short of representing the requirements of modern draftsmanship.

LUCIEN E. PICOLET.

GLYCEROL AND THE GLYCOLS. Production, Properties and Analyses. By James W. Lawrie, Ph.D. 447 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $9.50.

The fact that a volume of over 400 pages can be devoted to one compound shows vividly the enormous development of applied chemistry. Glycerol has been known for many years. It was obtained first by Scheele. It is by the way stated in this book that Chevreul called it "glycerol" but this seems improbable. The form of the name, strictly correct according to modern organic nomenclature, is of comparative recent use. It seems certain that Chevreul must have called it "glycérine," the French form. Actually, the name is an error in so far as it was merely given on account of slight sweetness, and it was often termed in time past "the sweet principle of fats." It is not contained in fats except in minute amount and in rare cases, but it is produced from the fats in the process of manufacture. When it first became a familiar article about the middle of the last century, its viscosity led to its being assumed to have some emollient action on the skin presumably a view aided by its being derived from oils and fats. In the scientific development or organic chemistry it was definitely recognized as an alcohol, the

proper termination given to it and it is no longer considered as suitable for application to the skin.

The manufacture of glycerol is now a very important industry, among others is its extensive application in the manufacture of the well known high explosives. For this purpose it must be of high purity.

In preparing this work the author has brought together in one compact well-printed volume all the important data concerning the manufacture, purification, and analytic control. An interesting summary of the early history is given and the several methods by which the substance is obtained are fully described. Much space is given to the production by fermentation. The physical properties and constants are set forth in detail, also the various reactions, the analytic methods and the international standards, and specifications. A chapter is devoted to the manufacture of nitroglycerin termed here in deference to the exact nomenclature "nitroglycerol." About thirty pages are devoted to the glycols among which, of course, one of the most familiar forms, ethylene glycol, is fully described. A brief chapter on the future of "glycerol" ends the main part of the text. In addition to the use for the manufacture of an explosive glycerol has been extensively employed as an anti-freeze for automobiles. It is stated that in 1926 over thirteen million pounds were used for this purpose. Perhaps the most interesting feature of glycerol production is that by fermentation. German chemists during the war perfected this method so that about one thousand tons were produced per month.

HENRY LEFFMANN.

ISOSTASY. By William Bowie, Chief, Division of Geodesy, U. S. Coast and Geodetic Survey, President, Section of Geodesy, International Geodetic and Geophysical Union. XIV–275 pages, 39 illustrations, 12mo. cloth, New York, E. P. Dutton & Company. Price, $5.00.

The word isostasy made its first appearance in a paper by Dutton, "On Some of the Greater Problems of Physical Geology" delivered before the Philosophical Society of Washington on April 27th, 1889. He would have preferred the word, "isobary" but it already had been preëmpted by the meteorologist. At the time of its inception Dutton employed the term "isostasy" to designate the state of equilibrium attained by a heterogenous body such as the earth under the influence of gravity and rotational stresses. Although isostasy retains to this day the meaning attributed to it by Dutton, numerous theories on just how the isostatic state is produced have arisen in later years and which seem to provide a more logical explanation than that set forth by Dutton. In the chapter on the development of the isostatic theory the author lays particular emphasis upon those of Airy and Pratt. Both these theories are elaborated to a greater extent in the chapters following. According to the author the Pratt theory seems to be the more acceptable. This theory postulates the earth's crust to be of uniform depth but composed of materials having a varying density. On the other hand, Airy's theory calls for a crust of uniform density and of varying thickness or depth.

The establishment of the existence of isostasy in the earth's crust has served to cast shadows of doubt over some of the earlier theories explaining the configuration of our terrestial sphere. An explanation for the disagreement between these

earlier and the present theories is found in the fact that the former were founded upon geological observations while the latter have been deduced from geodetic data. These geodetic data which chiefly consist of deflections of a plumb-bob from the vertical and gravity anamolies have been determined with a high degree of accuracy and are responsible for establishing beyond reasonable doubt the existence of isostatic equilibrium throughout the earth's crust. It is generally known that the earlier theories attempted to explain the configuration of the earth's surface by assuming a progressive cooling off of the earth with an accompanying shrinkage of the central mass or core. When such occurred the relatively rigid crust would tend to shrink, such a tendency resulting in a collapse of the crust at its weakest point and a subsequent pushing up or elevation of crustal matter due to pressure upon it in a horizontal direction. A close study of isostatic conditions indicate that such is not the case. All evidence leads to the assumption that the rising of portions of the earth's crust is caused by forces exerted in a vertical direction, any horizontal movement of matter being confined to plastic subcrustal material. As a corollary to the isostatic theory and contrary to the older theory the earth's crust is assumed to be relatively weak due to the fact that isostatic equilibrium of the crust is acquired readily even in comparatively small areas.

Evidently the author has taken pains to make his subject readily visualized and understood by the readers who are meeting for the first time this concept of isostasy. The liberal use of diagrammatic figures is particularly commendable. The reader should not be discouraged if he or she fails to grasp all details of the theory in the first chapter or two. This first portion is introductory and historical in nature and the various passing references are elaborated thoroughly in ensuing chapters. At the end of chapter eight the author has furnished a bibliography of geological literature relevant to his subject.

T. K. CLEVELAND.

SOLUBILITIES OF INORGANIC AND ORGANIC COMPOUNDS. A compilation of quantitative solubility data from the periodical literature. By Atherton Seidell, Ph.D. Supplement to the second edition containing data published during the years 1917–1926 inclusive. 568 pages, 8vo. New York, D. Van Nostrand Company, 1928. Price, $8.

This edition covers the whole alphabet beginning with "Acenaphthene" and ending with "Zirconium sulphate." There is in addition a comprehensive detailed index and list of authors. Comment on the book would merely repeat what has been said of the previous edition. The preparation of such a work is a great labor and draws heavily on the patience of the author, but the data are of great use to workers in chemistry and physics. The style of figure used is satisfactory and the arrangement of the data is in serviceable form. The main purpose of the present volume was to include many data not available when former edition was published. To republish the original volume with corrections and additions required by the progress of research would have involved very great cost, and the plan of issuing a supplementary volume is entirely commendable. The method of presenting the data and the form in which these are set forth are excellent.

H. L.

AMERICAN CHEMISTRY. A record of achievement, the basis for future progress. By Harrison Hale, Ph.D. Second Edition, ix–255 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928. Price, $2.50.

This being the second edition needs but passing notice. The author says properly that the years that have passed since the issue of the first edition have demonstrated the great value of chemistry in the world's affairs, and especially its importance in the United States. The record of American chemistry while creditable to those who have taken part in it was for many years somewhat inferior to that of a few other countries. It is a trite observation that Germany was the leader in this field and this was due to the equally cultivated theory and practice. Americans have shown great progress in fields in which practical work is dominant phase, such as machinery of all types, but in sciences in which theory is important, or in which the work must be done for the sake of the knowledge required without necessarily resulting in practical benefit America was for a long while inactive. Matters have greatly improved of late and excellent records are being made in the laboratories of this country. Concerning the book in hand the reviewer feels obliged to disapprove of the highly surfaced paper on which it is printed. This is due indeed to the numerous illustrations, but many of these could be omitted without loss of value to the book as they represent scenes and apparatus quite familiar to educated readers. There seems also to be a disproportionate attention given to those chemists who have accomplished practical results as compared with workers who have developed the field of pure chemistry.

H. L.

PROBABILITY AND ITS ENGINEERING USES. By Thornton C. Fry, Ph.D. Member of the Technical Staff, Bell Telephone Laboratories, Inc. xiv–476 pages, 8vo, cloth. New York, D. Van Nostrand Company, Inc., 1928. Price, $7.50.

Those who would achieve an applicable knowledge of the theory of probability will find themselves confronted with a task which demands the exercise of the most subtile logic as well as the acquisition of a wide diversity of analytical accomplishment. The effort is worth the while, the rapid strides of physical science have been made in part by enlisting its aid and the many new applications of science which have entered into the scheme of modern life have given rise to a host of new problems in which, again, solutions can only be effected by the methods of the theory of probability. Since the time of Fermat and Pascal, nearly every mathematician of note has made some contribution to the subject, perhaps because it has proved slow to yield a satisfactory general basis for the deduction of applicable formulation. The modern development of the theory has been in general taken upon a statistical basis rather than upon a foundation of pure and priori logic, but the author expresses a conviction that probability is not an experimental science.

Laying great stress upon logical considerations and utilizing very fully the multiplicity of mathematical devices which are the bequest of two centuries of mathematical genius, Dr. Fry has produced a treatise of a high quality of didactic value which deals deductively with fundamentals, derived theorems, and their application to typical problems of certain modern industries. The author is unsparing of explanation in analyzing the conditions and appraising the logic of a variety of problems which he introduces in unfolding the intricacies of the subject

into practical working methods, as well as generous in supplying in detail the steps in the derivation of formulas. Practical working methods, it may be noted, are of special interest in this subject which until recent times has often been more one of mathematical abstraction than one of practical utility except in the actuarial and financial fields and in the adjustment of observations by the widely used method of least squares.

The beginning of the subject is discussed in much the same sequence as is ordinarily found in texts on probability but it differs markedly from them in dwelling at length upon the logic of every theorem considered, and in the diversity of types of problems examined. In this part is included an illuminating explanation of the eulerian integral for determining the value of factorials which is later used in the derivation of the Stirling formula for the approximate value of the factorials of large numbers. Experimental probability with relation to Bernoulli's Theorem and Baye's Theorem and, further on, Distribution Functions occupy many pages of analytical and critical discussion. As is to be expected of an author who is a member of the technical staff of the Bell Laboratories, whose contributions to scientific literature are of a uniformly high order of excellence, many of the problems which are considered at length are those which arise in telephone service or in the functioning of telephonic equipment. Most of these problems, the development of which entails a variety of formidable analytical transformations, necessarily premise a familiarity with such equipment. The volume concludes with the application of probability to the kinetic theory of gases which is presented with its thoroughness characteristic of other parts of the volume. An appendix containing a number of tables including tables of factorials and logarithms of factorials, binomial coefficients and error functions. The work is notable in setting forth at great length the mathematical and logical complexities of modern applications of the theory of probability in unusually readable form quite in contrast with the terse and abstract language usual with the mathematician.

L. E. P.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 289. Forces on Elliptic Cylinder in Uniform Air Stream, by A. F. Zahm, R. H. Smith, and F. A. Loudon. 18 pages, illustrations, quarto Washington, Government Printing Office, 1928, price ten cents.

This report presents the results of wind tunnel tests on four elliptic cylinders with various fineness ratios, conducted in the Navy Aerodynamic Laboratory, Washington. The object of the tests was to investigate the characteristics of sections suitable for streamline wire which normally has an elliptic section with a fineness ratio of 4.0; also to learn whether a reduction in fineness ratio would result in improvement; also to determine the pressure distribution on the model of fineness ratio 4.

Four elliptic cylinders with fineness ratios of 2.5, 3.0, 3.5, and 4.0 were made and then tested in the 8 by 8 ft. tunnel; first for cross-wind force, drag, and yawing moment at 30 miles an hour and various angles of yaw; next for drag at 0° pitch and 0° yaw and various wind speeds; then for end effect on the smallest and largest models; and lastly for pressure distribution over the surface of the largest model at 0° pitch and 0° yaw and various wind speeds. In all tests, the

length of the model was transverse to the current. The results are given for standard air density, ρ = .002378 slug per cubic foot.

This account is a slightly revised form of Report No. 315, prepared for the Bureau of Aeronautics, July 13, 1926, and by it submitted for publication to the National Advisory Committee for Aeronautics. A summary of conclusions is given at the end of the test.

COLLOID CHEMISTRY. By T. Svedberg. 2d edition, revised by Arne Tiselius, 8vo., 302 pages, numerous illustrations. The Chemical Catalog Co., New York, 1928. $5.50.

This is one of the volumes of the series of monographs issued by the American Chemical Society and now constituting a large and valuable library of chemical literature. Being a second edition there is little to be said except to announce publication. The text is a report of lectures delivered at the University of Wisconsin in 1923. It should be added, however, that the revisor has added much new matter and carefully scanned the original material. The volume therefore includes a very large amount of information on colloid chemistry, the growth of which has been so striking a feature of the last quarter century in chemical research. Some historical data are given in the introductory portion, in which there seems to be a somewhat invidious allusion to Graham's work in so far as to enumerate some anticipations of him. Adumbrations of this character are common and may be made concerning almost all epoch-making discoveries or inventions. Da Vinci is sometimes given credit for initiating aviation, Lucretius has been thought to allude to motion pictures, and recently assertions have been made that wonderful anticipations of modern knowledge were stated by Roger Bacon. Graham introduced the word "colloid" into chemical literature and in his paper in *Philosophical Transactions*, stated that he regarded the difference between colloids and crystalloids as due to molecular differences. English readers will be impressed with the fact that the text was written in fairly good English by the Swedish author, but at the same time it would have been proper for an English speaking editor to have looked over the MS.

HENRY LEFFMANN.

RADIO. A study of first principles for schools, evening classes and home study. By Elmer E. Burns, Instructor in Physics, Austin High School, Chicago. xv–255 pages, illustrations, 20 x 13 cm., cloth. New York, D. Van Nostrand Company, Inc., 1928. Price, $2.

Since radio has become an established art of great importance, many books dealing with the subject have become available, most of them adapted to the needs of particular types of readers, sometimes too mathematical for any one but a college-trained person, again too rudimentary to convey applicable information. Professor Burns has found a very happy middle course. He begins at the beginning by first describing simple crystal sets, one-tube sets and amplifiers with enough quantitative data for a resourceful reader to build a set. In this part of the programme doubtless many of his readers will have already qualified. It is, indeed, interest of that sort which is often the beginning of a technical education and a life work. This is preliminary to what may be called, for want of a more suitable term, a proximate analyses of the subject which conveys a large amount of

satisfactory information on the principles and operation of the component elements of receiving sets.

The aim of the work is to present simply and clearly the fundamental principles of electricity and magnetism which it does without at any point losing sight of their application to radio. First we have electric batteries, the magnetic action of an electric current, and electric circuits and Ohm's law, which cover three chapters. From that point we deal wholly with radio in chapters on electron tubes, alternating currents, detectors and amplifiers, fundamentals of receiving circuits, oscillating and transmitting circuits, radio measurements and an appendix containing useful formulas and symbols.

It is difficult to say on what particular topic the book is at its best for their treatment is one of harmonious adequacy in their inter-relationship. The chapters on thermionic tubes will claim a goodly share of approval for their clearly expressed and well illustrated account of their properties, but other parts of the book compare very favorably with these on all matters of text-book performances. A conscientious study of this book insures the acquisition of sound and practical knowledge in applied radio and an excellent preparation for one who contemplates an exhaustive course of study in radio engineering.

LUCIEN E. PICOLET.

BALISTIQUE INTERIEURE THÉORIQUE ET TABLES NUMERIQUES. Par G. Sugot, Professeur a l'Ecole d'Application de l'Artillerie Navale. xxx–130 pages, illustrations, 25 x 14 cm., paper. Paris, Gauthier-Villars et Cie, 1928. Price, 40 francs.

BALISTIQUE EXTÉRIEURE THÉORIQUE. Par G. Sugot, Professeur a l'Ecole d'Application de l'Artillerie Navale. iii–94 pages, illustrations, 25 x 14 cm., paper. Paris, Gauthier-Villars et Cie, 1928. Price, 25 francs.

The design of a piece of artillery, like any other apparatus with constrained moving parts upon which certain determinate forces act, is purely an engineering problem in which the specifications of bore, rifling, weight of projectile and muzzle velocity are the fundamental data chosen within the possibilities of sound practice. Once the contour of the powder chamber and bore are determined, the process of mechanical design may proceed. Interior ballistics deals with all the factors which enter into the determination of these relatively simple dimensions. These factors are many and involved and entail thermodynamic considerations and experimental investigation of the properties of the powders used as a propellant, the work of whose varying pressure upon the base of the projectile, generally stated, must be equivalent to its kinetic energy at the muzzle plus resistances and losses during its transit through the bore.

These processes of coördinating the results of experiment with theoretical considerations constitutes the subject-matter of this specialized branch of ordinance engineering. The present volume which is an exposition of these theoretical and experimental methods are included in the course of study at the Ecole d'Application de l'Artillerie Navale. The work is in two major divisions, the motion of the projectile in the bore, and numerical processes. The first comprises equations of interior ballistics, ballistic analogies, constant emission powders, variable emission powders, summary and conclusions. The second part comprises

a general survey, determination of the characteristics of B-powders, theoretical derivation of working formulas of Ch.S., derivation of the experimental working formulas of Dupuis, practical value of the working formulas, certain constants derived from theoretical working formulas. The numerous tables which are vital to a subject of this kind are placed at the beginning of the volume. Particularly for the use of foreign readers a key to symbolization which does not appear to be included would be decidedly helpful, especially if the book is used for reference. The work is a highly analytical exposition of modern methods in interior ballistics.

As distinguished from a consideration of the forces which act upon the projectile before it reaches the muzzle of interior ballistics, the problems of analysis of the behavior of the projectile after leaving the muzzle, of exterior ballistics, are varied and difficult and their solution likewise enlists the coördination of experiment with theory. General Charbonnier, the author of a comprehensive treatise on the subject has aptly termed that branch of the art "terrestiial astronomy."

The present volume is devoted to the theoretical and deductive processes of the subject. According to the paging of the volume from p. 827 to p. 920 and a foot note referring to volumes I and II of Traite de Balistique Exterieure by the same author, it presumably forms a part of that work though there is no indication on the title page of any relation to those volumes. The five divisions of the work cover: ballistics of a material point; motion of the projectile about its center of gravity; influences affecting trajectory; practical methods of ballistic computation. Like in its companion work, the analytical deductions are very fully developed.

L. E. P.

MARVELS OF MODERN MECHANICS. The Mastery of Land, Sea and Air. By Harold T. Wilkins. xi–280 pages, 21 x 14 cm., illustrated, cloth. New York, E. P. Dutton & Company. Price, $3.

Almost daily some new achievement in applied science is being brought to our attention. The list is already a long one, and it continues to grow until the mind becomes confused in endeavoring to recall the essential details of even the more important ones. Several decades ago we had the deservedly popular books of adventure of Jules Verne whose stories were woven about a framework of applied science with rarely if ever a fault of technique, with the possible exception of a novelist's license to strain a scientific fact to effect a suitable denouement. Since that day, applied science has become interesting enough *per se* to require no background of fiction to enlist interest, and several books descriptive of a variety of "wonders of science" and the like have since that time made their appearance. Mr. Wilkins steps into the field to bring these matters thoroughly up to date and the term "mechanics" in this title is in a rather comprehensive sense in that the foundation of physical science rests upon the principles of mechanics. However the book deals almost entirely with purely mechanical developments, though an exception here and there occurs as for instance in the mechanics of the telegraphic transmission of pictures and in dealing with phenomena of electricity and light and other radiations, and some chemical matters.

As the author states, the book is a summary of modern achievement in the laboratory and experimental science and wherever power is used. A complete summary of such a scope would require several volumes like the present, but the

collection is very extensive and is representative of many devices and methods of a scientific character which at the time of their inception created widespread interest and sometimes amazement at their revolutionary character. Among these it is only necessary to mention the X-ray, aerial navigation, applications of the gyroscope, wireless and radium, the extensive applications of which have now become familiar. Many other topics of deep and timely interest are discussed, such as salvaging sunken ships, submarine cable laying, archeological excavation and scenic effects in the theatre. The discourse is informal, precise and highly informative. There is no index and names of inventors and dates are not as generously supplied as might be desired in a book of reference. However as a means of entertainment for those who desire a deeply interesting account of representative achievements in applied science, the book very adequately meets that requirement.

LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

American Chemistry, by Harrison Hale, Ph.D. Second Edition. 255 pages, illustrations, 8vo. New York, D. Van Nostrand Company, Inc., 1928, price $2.50.

Glycerol and the Glycols Production, Properties and Analyses, by James W. Lawrie, Ph.D. American Chemical Society Monograph Series. 447 pages, illustrations, tables, 8vo. New York, The Chemical Catalog Company, Inc., 1928, price $9.50.

A First Course in Physics for Colleges, by Robert Andrews Millikan, Ph.D., Henry Gordon Gale, Ph.D., and Charles William Edwards, M.S. 676 + XLII pages, illustrations, plates, 8vo. Boston, Ginn and Company, 1928, price $3.72.

An Epitome of Swedenborg's Science, by Frank W. Very, S.B. 2 volumes, plates, portrait, 8vo. Boston, The Four Seas Company.

Colloid Chemistry by The Svedberg. Second Edition revised and enlarged by Arne Tiselius. American Chemical Society Monograph Series. 302 pages, illustrations, diagrams, 8vo. New York, The Chemical Catalog Company, Inc., 1928, price $5.50.

National Advisory Committee for Aeronautics. Technical Notes, No. 294. Wind tunnel force tests in wing systems through large angles of attack, by Carl J. Wenzinger and Thomas A. Harris. 7 pages, diagrams, quarto. No. 295. The effect of tip shields on a horizontal tail surface, by Paul V. Dronin, Earl I. Ramsden and George J. Higgins. 10 pages, tables, diagrams, quarto. Washington, Committee, 1928.

Introduction to Modern Physics, by F. K. Richtmyer. 596 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, 1928, price $5.00.

A Text-Book of Inorganic Chemistry, edited by J. Newton Friend, D.Sc. Volume VI, part I, Nitrogen, by Edmund B. R. Prideaux and Herbert Lambourne, 242 pages, illustrations, 8vo. Volume X, The Metal-Ammines by Miss M. J. Sutherland. 260 pages, 8vo. London, Charles Griffin and Company, Ltd., Philadelphia, J. B. Lippincott Company, 1928.

CURRENT TOPICS.

High Angular Velocities Obtained by Rotors having no Solid Axis. E. Henriot and E. Huguenard. (*Jour. de Phys. et Rad.*, Nov., 1927.) Hitherto we have had rotors with rigid shafts and, on the other hand, rotors with flexible axes or flexible bearings. Flexible shafts have the advantage of taking care of errors of centering by bending so that the center of gravity of the rotor falls upon the axis of rotation when the critical speed is exceeded. Nevertheless it has been the rigid shaft to which recourse has been generally had when high speeds of rotation have been required as, for example, for Foucault mirrors. Perfection of centering has been aimed at but the results have been none too good in spite of the high costs and difficulties of construction. Now the authors have devised rotors that are supported by sheets of gas and that can be rotated an incredible number of times per sec. They began by working with small rotors. Their success in this field led them to try to use rotating parts weighing several kilograms. Here also their method worked well.

A jet of gas escaping upwards from a conical orifice supports a steel ball at a distance of several cm. from the opening. The stability of the ball is, however, slight. The authors found that the ball is very stably supported when it is only a fraction of a mm. from the sides of the aperture. If it be placed a few mm. from the sides, it is drawn in close even if the gas be flowing out under the pressure of 100 atmospheres. In the experiments of this paper the gas not only supports the rotor but also makes it rotate. The stator is a hollow cone into which discharge air or carbon dioxide arriving through pipes under pressures ranging from 1 to 6 kg. per sq. cm. The tubes make an angle of 45° with planes tangent to the cone. The rotor also is conical in form, though the angle of its cone is greater than that of the stator. With a rotor 45 mm. in diameter 1,300 revolutions per sec. were obtained with a peripheral speed of 185 meters per sec. With a rotor 11.7 mm. in diameter the corresponding results were 11,000 r.p.s. and 404 m./sec. It is difficult to comprehend that the spinning part, less than half an inch in diameter, revolved so fast that a point on its circumference was travelling at the rate of 840 miles an hour. Later small steel mirrors were mounted on the small rotor but they reduced the speed greatly. Even with mirrors only 4 or 5 mm. on a side the churning of the air kept the number of revolutions down to about

5,500 per sec., but even so measurements are being made on the velocity of light over a distance as small as one meter. It was discovered that stability and certainty of action were increased by using heavier rotors, and application was made to the driving of centrifuges where the containing cylinder was either on top of the rotor or hung beneath it, the rotor itself being under the stator and supported there by the suction of the escaping gas.

One advantage of the gas bearing is that parts can be used for rotation that are only roughly centered. In one instance a weight of 100 g. was put 2 cm. from the axis and the whole made to rotate 1,000 times per sec. The mass of the unaugmented rotor seems to have been about 700 g. In such cases it is advisable to support the stator elastically so that the rotor out of center may not strike the fixed part.

The rate of revolution was measured streboscopically, by acoustical methods and by mechanical means. The authors point out that with a rotor of 6 mm. radius making 10,000 r.p.s. the centrifugal force at the periphery amounts to about 2,400,000 times the force of gravity, and that in the 6 mm. from circumference to center this force dwindles to zero. In centrifuges carrying discs of lead the centrifugal force was 150,000 that of gravity and the cold lead in a few minutes flowed away from the middle and heaped up at the circumference. G. F. S.

The Electrodeless Discharge through Gases. SIR J. J. THOMSON. (*Proc. Phys. Soc.*, London, April 15, 1928.) "By 'electrodeless discharge' I mean a discharge where the currents form closed circuits in the gas, and have not to pass from gas to metal, as in discharge tubes with metallic electrodes, or from gas to glass, as when metallic electrodes are placed outside the tube. This ring discharge can be produced by placing outside the bulb or tube containing the gas at a low pressure a solenoid placed in a circuit connecting the outsides of two Leyden jars. The insides of these jars are connected respectively with the two terminals of an induction coil; when sparks pass between these terminals, rapidly alternating currents, whose frequency is inversely proportional to the square root of the product of the capacity of the jars and the self-induction of the circuit, pass through the solenoid. The electromagnetic induction due to these currents starts in the exhausted vessel currents which flow in rings whose axis coincides with that of the solenoid." For a long time it has been recognized that letting light fall on a spark-gap makes it easier for the spark to pass. This is dueto the effect of the light on the negative terminal whereby electrons are set free. The electrodeless discharge affords excellent

opportunities for examining the effect of light and other agents upon discharge through gases. The discharge tube was spherical in form and had opening into it two long tubes one the prolongation of the other. Light entered one tube through a quartz window, passed through the spherical space and made its exit by the second tube, so that of all the apparatus only the ends of the two tubes were struck by the light. The voltage of the induction coil was reduced until the ring discharge just ceased. The passage of the light was followed by the appearance of the discharge. This effect takes place in air, hydrogen, helium, argon, oxygen, nitrogen, carbonic acid, iodine vapor and mercury vapor. It is not as pronounced at low pressures as at somewhat higher ones. It has been observed in air for pressures ranging from .007 to 7 mm. The effect is caused by light from various sources, from a mercury lamp, an arc lamp, from a spark between metal terminals or from a brush discharge. A spirit lamp gives light that produces the result as does a Bunsen burner or an oxyhydrogen flame. To be effective the light must not pass through anything that absorbs ultra-violet light. Thin films of glass or mica do this and keep the ring discharge from occurring, while quartz and rock salt let the discharge appear. "The effect of illumination on the ring discharge is evidently due to the absorption of ultra-violet light. The energy absorbed, though not sufficient to eject electrons from the atoms or molecules of the gas, may be sufficient to put these for a time, which is not infinitesimal, into a state in which they are more easily ionized than when they are normal. Thus, as the work of ionisation is already half done, the external electric field will not be called on to supply as much energy to the free electrons to make them ionize these excited molecules as would be required to make them ionize normal atoms or molecules; and thus the ring discharge will pass more easily when the gas is illuminated than when it is not."

Interesting effects due to impurities in the gas have been observed. Furthermore the electrodeless discharge makes the gas active chemically and causes it to form unexpected compounds. For example, the discharge was formed in oxygen in a tube that contained MgO. The light from the discharge makes the magnesia phosphoresce. It was noted that the pressure of the oxygen fell quickly. Oxygen having a volume equal to many times that of the MgO was introduced and disappeared. The compound had the same appearance but that it had really changed was shown by its ceasing to phosphoresce. He concludes that "oxygen through which the ring discharge is passing combines with MgO to form a higher oxide. I understand that a higher oxide of magnesium is manufactured in considerable quantities, though it is not mentioned

in the majority of text books on chemistry." By the same method higher oxides of calcium and zinc were produced. G. F. S.

The Origin of the Aurora Borealis. E. O. HURLBURT. (*Terrestrial Mag.*, March, 1928.) "A theory of the aurora borealis has been developed by Birkeland, Stoermer, Vegard, and others on the assumption that the aurora is caused by charged particles emitted from the Sun which under the influence of the magnetic field of the Earth are diverted to the polar regions. There their energy is given to the atmosphere and by some process is converted partially or totally into the auroral light." There are objections to this explanation from the side of theory as well as from that of experiment. For instance no one has succeeded in reproducing the spectrum of the aurora in the laboratory.

The author ventures to suggest a new theory. The energy that finally appears with auroral light comes from the sun in ultra-violet radiation. In the higher part of the earth's atmosphere it is absorbed with the production of ions and electrons. These particles diffuse but combine to only a slight extent. The ions drift along the magnetic field of the earth and concentrate in the polar regions. In lower levels there they recombine and the energy of combination appears in the auroral light.

From observations made in Maine, August, 1927, the power of the auroral light then seen is calculated to have been 10^{15} ergs/sec. This agrees sufficiently well with the results of another computation based on the rate of flow of ultra-violet light to the earth. The author wisely remarks "But here I must stop, partly to avoid being too rash, but mainly to admit that my contemplation of the aurora has been too limited to give that steadying of ideas which comes only from experimentation." G. F. S.

The Application of Electrical Resistance Measurements to the Study of the Atmospheric Corrosion of Metals. J. C. HUDSON. (*Proc. Phys. Soc.*, London, April 15, 1928.) The effect of atmospheric corrosion upon metals can be traced by a study of the weight of the specimen as time goes on. Vernon has done this "and the accuracy obtainable is well demonstrated by the fact that he was able to follow the development of tarnish films on lead and aluminium in cases where the final weight increment, after 25 days' exposure, was as low as 0.28 milligrammes." Much labor is, however, necessary especially when the specimen is exposed in the open where the products of chemical action may be carried away by rain or otherwise lost. When, therefore, the Atmospheric Corrosion Committee of the British Non-Ferrous Metals Research

Association appointed the author to make systematic field tests he proceeded to devise a method that should be both more accurate and more convenient. He thus developed a previously existing procedure in which the extent of corrosion of a metallic conductor is indicated by the increase in its electrical resistance. As corrosion goes on metal is replaced by non-conducting products of chemical action. Thus the cross-section of the metal grows less and the resistance becomes greater. "Since the resulting percentage increase in the resistance of the specimen is equal to the percentage diminution in the cross-section, the method has the advantage of giving results that are immediately comparable for different materials." In addition specimens of convenient size can be used and the same specimen can be continuously observed.

Thin wires show a greater percentage change in their resistance than do thick ones but the results suffer in accuracy from irregularities of the surface. Hence 18 S.W.G. was the standard size selected. About 200 cm. of the wire was wound into coils. Three such coils of the same metal were exposed to the atmosphere while a fourth control coil was kept in the laboratory. The preliminary cleansing of the metal and the attachment of terminals were well cared for. The resistance was determined by a Wheatstone bridge method. An increase of any per cent. in the resistance means that the effective cross-section has diminished by the same per cent., the assumptions being that the corroded film is uniform in thickness and that there is a sharp boundary between the untouched metal and the corroded parts.

Wires of the same gauge of nickel, copper, copper-nickel, phosphor-bronze, nickel-silver, cadmium-copper, and brass were exposed to the weather for 53 days. Brass showed the greatest change of resistance, from 2.65 per cent. to 3.79 per cent. according to composition. Copper-nickel was least affected, 1.49 per cent. Copper wire was measured at the end of different periods. One specimen after 101 days gained .88 per cent. in resistance, after 213 days, 3.99 per cent. and after 381 days 4.82 per cent. The change of resistance was found to be inversely proportional to the diameter of the wire when short periods of exposure are omitted from consideration. The rate of corrosion was shown to be much greater in winter than in summer.

It is evident that a method of considerable practical utility has been developed and successfully applied. G. F. S.

Some Observations of Atmospheric-Electric Potential-Gradient on Mountain Peaks in the Peruvian Andes. W. C. PARKINSON. (*Terrestrial Mag.*, March, 1928.) The Department of Terrestrial

Magnetism maintains an observatory at Huancayo, Peru. Here on a fairly level plain at an altitude of 11,000 feet continuous registration is made of electric air-potential. In May, 1927, a continuous record was taken on a hill elevated 500 feet above the plain and somewhat later the apparatus was transferred to a ridge 2,200 feet higher than the observatory. A consideration of average values of the gradient shows that both on hill and ridge it reaches a minimum value at 6 A.M. and a maximum at 10 A.M. For the hill the minimum and maximum averages are about 41 and 214 volts per meter while the corresponding values on the ridge were 48 and 337 volts/m. The gradients on the hill were about 2.17 times as great as those at the observatory while those on the ridge were 3.06 times as great. It might have been expected that the difference between the values on hill and ridge would be larger but the contours of the two elevations must be taken into account.

G. F. S.

A Proposition of Leibniz for Extended Observations of the Earth's Magnetism. (*Terrestrial Mag.*, March, 1928.) After the foundation of the Royal Academy of Sciences in Berlin Leibniz addressed a memorial to the king of Prussia, Frederick I, in which he recommended that missionaries should receive special scientific training and should thereafter be sent to Russia, Turkey, Persia, India and China. There in addition to their religious activities they should act both as teachers of science and as investigators. The king was advised to attach to the minister to Russia a young man who had received the preliminary scientific training in the hope that Peter the Great might send him into the provinces to make observations on terrestrial magnetism. The czar's interest in navigation was well known and moreover the Englishman Halley had just made a magnetic chart on which lines ran through places having the same declination. These lines were drawn only on the water areas of the earth and stopped where the land began. Leibniz desired the king to have magnetic observations taken in his own territories and to have them made in the Orient as well through the goodwill and help of the czar, adding "Such an undertaking would be no less glorious for your Royal Majesty and useful for the public than it would be advantageous for the Christian work of missions." At least on the secular side Dr. L. A. Bauer and the Carnegie Institution of Washington have carried the suggestion to a successful issue.

G. F. S.

Atmospheric Dust and Condensation Nuclei. R. K. BOYLAN. (*Proc. Royal Irish Acad.*, Vol. 37, A, No. 6.) There is confusion

arising from identifying the dust particles in the air with the nuclei on which water vapor condenses. An Owens jet dust counter was used to get the number of particles of dust in unit volume and an Aitken's Pocket Dust-Counter did the same service for the nuclei. Observations extending over eight months failed to disclose a single instance when the number of dust particles in a cu. cm. was the same as the number of nuclei in the same volume. Indeed the nuclei always vastly outnumbered the dust particles, not infrequently in the ratio of 30 : 1. Rain reduced the number of dust particles and slightly increased the nuclei. Fog greatly augmented the number of both. A correlation coefficient of .73 was calculated for the occurrence of the two types of particles. This points to a common origin.

Observations were made at 15 min. intervals in a room in which a lamp was lighted at 3:30 p.m. and put out at 4 o'clock.

Time	3	3:15	3:30	3:45	4	4:15
Nuclei per cc.	15,600	15,800	16,000	33,000	100,000	34,000
Dust per cc.	—	600	635	1,450	1,540	1,150

The dust content of rooms was artificially varied by sweeping accumulations of dust or by setting free the contents of a vacuum cleaner bag. While the dust count was always very greatly increased, the number of nuclei never increased in the same ratio. Indeed the introduction of vacuum cleaner dirt usually reduced the number of nuclei. Another series of experiments showed that, even when ordinary nuclei have been filtered out of air, dust particles will not serve as centers of condensation. Moreover dust particles and nuclei readily unite so that the setting up of heavy clouds of dust does away with every nucleus previously present.

G. F. S.

Health of Workers in Dusty Trades.—The United States Public Health Service has completed a study of the health of workers in a Portland cement plant, the first of a series covering the dusty trades, according to an announcement recently made by Surgeon General H. S. Cumming. The study was undertaken to ascertain whether persons working in an atmosphere containing numerous minute particles of a calcium dust suffered any harmful effects. The investigation was conducted in one of the older, dustier plants, so that the effect of large quantities of the dust could be observed. Records of all absences from work were kept for three years, and the nature of disabling sickness was ascertained. Physical examinations were made, X-ray films taken, and the character and amounts of dust in the atmosphere of the plant were determined.

The results of this investigation indicated that the calcium dusts generated in the process of manufacturing Portland cement do not predispose workers to tuberculosis nor to pneumonia. The workers exposed to dust experienced, however, an abnormal number of attacks of diseases of the upper respiratory tract, especially colds, acute bronchitis, diseases of the pharynx and tonsils, and also influenza, or grippe. Attacks of these diseases serious enough to cause absence for two consecutive working days or longer occurred among the men in the dustier departments at a rate which was about 60 per cent. above that of the men in the comparatively non-dusty departments. Limestone dust appeared to be slightly more deleterious in this respect than cement dust.

Outdoor work in all kinds of weather such as was experienced by the quarry workers appeared to predispose to diseases of the upper respiratory tract even more than did exposure to the calcium dusts. In the outdoor departments of the plant, also, the highest attack rates of rheumatism were found. The study also indicated that work in a cement dusty atmosphere may predispose to certain skin diseases such as boils, to conjunctivitis, and to deafness when cement dust in combination with ear wax forms plugs in the external ear. When the dust in the atmosphere is less than about ten million particles per cubic foot of air it is doubtful that the above-mentioned diseases and conditions would be found at greater than average frequency.

Modernization of plants and installation of ventilating systems are helping to solve the dust problem of the industry.

Measurement of the Biologically Active Ultra-Violet Rays of Sunlight. L. HILL. (*Proc. Royal Soc.*, A 774.) A standard solution of methylene-blue was made and acetone was added. Ultra-violet light decomposes the acetone and the methylene-blue acting as a hydrogen acceptor is changed in color. The bleaching is in proportion to the duration of exposure, provided the radiation is constant. The standard solution is kept in brown glass bottles but for use is contained in a silica tube. This acetone-blue solution in a layer 3 mm. thick transmits the line 3342 Å. U. of the mercury vapor lamp, partly absorbs 3132 Å. U. and transmits nothing shorter than this wave-length. After the blue solution had been acted on by radiation its color was compared with that of a series of eight tubes fixed and unbleachable in color, in which the degrees of the color scale were equal as biologically standardized through the killing of bacteria and the production of erythema on the human skin.

"Ultra-violet rays reach us diffusely from the blue sky and

bright clouds as well as direct from the sun. Dorno has shown that the ultra-violet radiation from the clear sky at Davos is greater than from the low sun. The silica tube containing the standard acetone-blue solution must then be exposed to the sky right down to the horizon line. At one station the reading appeared to be 30–40 per cent. too low. The full exposure of the tube to the sky was found to be obstructed by trees. It was agreed that the tube should be exposed in future on the top of a tall mast. The readings continued to be too low. The tube was then found to be screened from the northern half of the sky by an obstruction on the top of the mast. On raising the tube above the obstruction the true readings were obtained."

A series of determinations was made over a period of more than two years and at several places in England. The effect of the ultra-violet light was strongest in June and weakest in February and November. "Places remote from towns, such as Peppard Common and the top of Hamstead, which is singularly free from smoke during the greater part of the year owing to its height and position to the northwest of London, receive considerably more ultra-violet light than those more exposed to the smoke clouds of industrial areas. Ultra-violet intensity is clearly more dependent upon artificial air pollution than to natural causes due to geographical position in England." Davos in Switzerland gets more ultra-violet radiation than the most favored place in England but Assouan in Egypt gets more than Davos. G. F. S.

Confusion worse Confounded. It was said in the '70's of the last century in medical circles that the use of potassium chlorate in American medical practice (now fortunately almost abandoned) was due to a mistranslation from the German, the original article recommending "kalium chloratum," which is potassium chloride, but taken by the translator as meaning potassium chlorate, which latter would be in German "kalium chloricum." Whether this statement is or is not true, there are many instances in which erroneous translations have caused serious misleadings.

The prompting for this introduction is the confusion that has crept into the discussions as to the effects of baking powders using alum, generally in the form of sodium alum. With curious frequency, the parties engaged in this widespread and somewhat acrimonious dispute, talk about the effects of "alum," when there is no alum in the material after the leavening has taken place. Baking powders are always made with a slight excess of carbonate and the whole of the aluminum salt is transformed into aluminum hydroxide. In an article recently published in *Science* (1928, 68, 161)

being the current number (August 17) repeated statements are made that "alum" occurs in fruits, vegetables, and meats, whereas the statement should be that "aluminum" so occurs. There is no alum of any kind in the article served at our tables. Alum is found in the ordinary kitchen only in the unchanged baking powder. One sentence from the article will serve to show the peculiar misuse of the term. "Analyses of agricultural products made by Langworthy and Austen in the Department of Agriculture, show the quantities of alum in our agricultural food products to be extremely minute." The total amount of "alum" in these products would be correctly represented by "decimal nought."

H. L.

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THE FUNDAMENTALS OF ELECTRODYNAMICS.*

BY

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Statement of the Fundamental Equations.—The laws of electrodynamics are embodied in the well-known scheme of equations [1]

$$1/c(\rho\mathbf{u} + \partial\mathbf{E}/\partial t) = \text{curl } \mathbf{H}, \tag{1}$$

$$\rho = \text{div. } \mathbf{E}, \tag{2}$$

$$-\frac{1}{c}\frac{\partial\mathbf{H}}{\partial t} = \text{curl } \mathbf{E}, \tag{3}$$

$$0 = \text{div. } \mathbf{H}, \tag{4}$$

together with a fifth relation whose aim is to describe the law of motion of an electron. This law states that the electron is a spherical shell of charge when viewed in a system of axes in which its center has zero velocity, and that in this system of axes, its acceleration and the other time derivatives of its motion are determined in such a manner that

$$\iiint \rho\mathbf{E}d\tau = 0. \tag{5}$$

* Lecture given at Columbia University on August 3, 1928.

[1] The units here used are the Heavisidian units, in which the unit of charge and unit magnetic pole are respectively $1/\sqrt{4\pi}$ times the electrostatic and magnetostatic units.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.)

In the above equations, ρ is the charge density, **E** and **H** the magnetic field **u** the velocity, $d\tau$ an element of volume, and c a constant, which experiment shows to be equal to the velocity of light in vacuo.

It is customary to express (5) in another form. We first split the integral into two parts, one pertaining to the field $\mathbf{E}_i\mathbf{H}_i$, produced by the charge on the electron itself, disentangled from the total field in a manner to be explained later and the other, the field $\mathbf{E}_0$, $\mathbf{H}_0$, due to all the remaining charges of the system. Equation (5) may then be written

$$\iiint \rho \mathbf{E}_0 d\tau = -\iiint \rho \mathbf{E}_i d\tau. \tag{6}$$

It is possible to calculate $\mathbf{E}_i$ in terms of the acceleration $\ddot{\mathbf{S}}$, rate of charge of acceleration, $\dddot{\mathbf{S}}$, and higher time derivatives of the motion, so that expressing the right hand side of (6) in this way, the equation assumes the form

$$\iiint \rho \mathbf{E}_0 d\tau = \frac{e^2}{6\pi a c^2}\ddot{\mathbf{S}} - \frac{e^2}{6\pi c^3}\dddot{\mathbf{S}} + \cdots, \text{ etc.} \tag{7}$$

where a is the radius of the spherical shell, and e the electronic charge.

The left hand side of (7) being called the external force on the electron, the quantity $e^2/6\pi a c^2$, which is the coefficient of the acceleration on the right hand side is appropriately known as the mass of the electron, it being understood that (7) is applicable only to the case when the velocity of the electron is zero in the system of axes to which **E** and **H** are referred. In many cases it is customary to neglect altogether the terms on the right hand side of (7) other than the first, and to assume moreover that the external field is constant over the electron. In this case, (7) assumes the form

$$e\mathbf{E}_0 = e^2\ddot{\mathbf{S}}/6\pi a c^2. \tag{8}$$

In extending the law of motion of the electron to cases where the velocity of the electron is not zero in the system of axes in which **E** is measured, it is customary to invoke the assumption of the restricted theory of relativity which,

at any rate for the case where $\mathbf{E}_0$ and $\mathbf{H}_0$ may be assumed constant over the electron, leads via (7) to the result [2]

$$e\left(\mathbf{E}_0 + \frac{[\mathbf{wH}_0]}{c}\right) = \frac{d}{dt}\left\{ m_0\mathbf{w} \Big/ \sqrt{1 - \frac{w^2}{c^2}} \right\}$$

$$+ \text{ terms involving higher time derivatives} \quad (9)$$

where $m_0 = e^2/6\pi ac^2$, and w is the velocity of the center of the electron. For the case of an acceleration parallel to the velocity, the first term on the right hand side of (9) assumes the form $m_0\dot{\mathbf{w}}/(1 - w^2/c^2)^{3/2}$, and for the case of an acceleration perpendicular to the velocity it assumes the form $m_0\dot{\mathbf{w}}/(1 - w^2/c^2)^{1/2}$. We consequently speak of

$$\text{The Longitudinal Mass } \frac{e^2}{6\pi ac^2}\left(1 - \frac{w^2}{c^2}\right)^{-3/2},$$

and

$$\text{The Transverse Mass } \frac{e^2}{6\pi ac^2}\left(1 - \frac{w^2}{c^2}\right)^{-1/2}.$$

On the foregoing view, the quantity which is really measured when the mass is measured for small velocities is the quantity $e^2/6\pi ac^2$, and the value of a is then calculated as the radius of a sphere which would give rise to that mass.

Historical Survey.—At the time when Maxwell commenced his epoch making investigations the known laws of electrodynamics were summed up in conclusions which are the analytical equivalent of the following: [3]

$$4\pi I = \oint \mathbf{H}_s ds, \quad (10)$$

[2] If $\mathbf{E}_0$, $d\tau$, and $\mathbf{H}_0$ are not constant over the electron, the left-hand side of (9) would assume the form $\int\int\int \rho(\mathbf{E}_0 + [u\mathbf{H}_0]/c)d\tau$, but with the various elements of the integral calculated at different times.

[3] We are confining ourselves to the case of free æther, so that we use $\mathbf{H}$ instead of $\mathbf{B}$ in (11). The introduction of $\mathbf{B}$ and $\mathbf{D}$ into the discussion would carry with it more complexity of an irrelevant kind than is worth while for the purpose of the present historical survey. Our units are here, of course, the ordinary electromagnetic units, since the introduction of Heavisidean here would add needlessly to the apparent artificiality of the equations of the pre-Maxwell period.

expressing the fact that the line integral of the magnetic field around a closed circuit encircling a current I is equal to $4\pi I$.

Then we have the relation

$$\frac{-d}{dt}\int\int \mathbf{H}_n dS = \oint \mathbf{E}_s ds, \tag{11}$$

expressing Faraday's law, that the rate of change of the surface integral of the normal component $\mathbf{H}_n$ of the magnetic field taken all over a cap bounded by a circuit is equal to the negative of the line integral of the electric field taken all around the circuit. Finally we have a law having to do with the mechanical forces on a circuit carrying a current, and equivalent to the statement that in the case of a number of circuits expressed by generalized coördinates q_r, the generalized force F_r necessary to hold the circuit in position against the actions of the other circuit is [4]

$$F_r = I_r \frac{\partial}{\partial q_r}\int\int_r \mathbf{H}_n dS. \tag{12}$$

The negative of this quantity, $f_r(= - F_r)$ is the generalized force on the circuit due to the other circuits, so that:

$$f_r = - I_r \frac{\partial}{\partial q_r}\int\int \mathbf{H}_n dS, \tag{13}$$

which is the form in which the expression is usually thought of.

Equation (13) is of course the analytical equivalent of the law obtained by calculating the forces between the current circuits by treating them in terms of their equivalent shells, and it is also the analytical equivalent of the statement that the forces on a current circuit as a whole, due to the other circuits is the same as that obtained by attaching to each element of length ds of the conductor a force δf_r, given by

$$\delta f_r = [I_r \cdot \mathbf{H}]\delta s. \tag{14}$$

[4] The directions are such that viewing the circuit from that side from which the current appears to flow counter-clockwise, the positive direction of the normal is drawn from the observer through the cap.

Maxwell set himself the task of moulding equations (11) and (12) into a form which made them appear as the outcome of general dynamical laws.

In the hands of Maxwell, equation (10) amounted practically to a definition of **H** in terms of the currents. It is not difficult to show that (10) contains as an analytical consequence, that insofar as **H** is determined by the current alone, the flux of **H** through any circuit denoted by subscript r, is given by

$$\iint \mathbf{H}_n dS = L_{1r}I_1 + L_{2r}I_2 + \cdots L_{rr}I_r, \tag{15}$$

where the L's are the ordinary coefficients of self and mutual induction, and are perfectly definite functions of the geometry of the system, given by

$$L_{mn} = \iint \frac{\cos \varphi ds_m ds_n}{r}, \tag{16}$$

φ being the angle between the elements ds_m and ds_n of the circuits concerned.

Thus, Faraday's law (11), for the circuit r becomes

$$-\frac{d}{dt}(L_{1r}I_1 + L_{2r}I_2 + \cdots L_{rr}I_r) = p_r, \tag{17}$$

where p is the electromotive force $\left(= \int \mathbf{E}_s ds\right)$ produced in the circuit as a result of the varying currents in that circuit and the other circuits. Or, if $P_r = - P_r$ is the generalized *external* force necessary to result in the condition of changing currents in the circuit r.

$$\frac{d}{dt}(L_{1r}I_1 + L_{2r}I_2 + \cdots L_{rr}I_r) = P_r. \tag{18}$$

Again, the law (12) for the generalized force acting on the circuit r becomes [5]

$$F_r = I_r\left(I_1\frac{\partial L_{ir}}{\partial q_r} + I_2\frac{\partial L_{2r}}{\partial q_r} + \cdots I_r\frac{\partial L_{rr}}{\partial q_r}\right). \tag{19}$$

[5] Of course, $\partial L_{rr}/\partial q_r$ is zero, and is merely included for symmetry.

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[5] Of course, $\partial L_{rr}/\partial q_r$ is zero, and is merely included for symmetry.

Thus the problem is to represent (18) and (19) as a consequence of generalized dynamics. The procedure is now almost obvious. Lagrange's equations for generalized coördinates are of the form:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial q_m}\right) - \frac{\partial T}{\partial q_m} = \Phi_m, \tag{20}$$

where Φ_m is the generalized force associated with the coördinates q_m. Suppose, in addition to the mechanical coördinates q_m, we think of electrical coördinates which we shall make appear only in our kinetic energy function through their velocities, which we shall associate with the various currents I_1, I_2, $\cdots$. Suppose in fact, we take for T the expression:

$$T = \tfrac{1}{2}L_{11}I_2^2 + L_{12}I_1I_2 + L_{13}I_1I_3 + \cdots \tfrac{1}{2}L_{22}I_2^2 + L_{23}I_2I_3 + L_{24}I_2I_4 + \cdots \text{etc.} + T_m, \tag{21}$$

where T_m is the expression we should have for the kinetic energy of the matter of the wires in the absence of any currents. Then, applying Lagrange's equations to the electrical coördinate represented as regards its velocity by I_r, we obtain (since T does not involve the electrical coördinates)

$$\frac{d}{dt}(L_{1r}I_i + L_{2r}I_2 + \cdots) = P_r, \tag{22}$$

which is the same as (18), the equivalent of the Faraday law. And, by applying the equations to the mechanical coördinate q_r, we obtain

$$I_r\left(I_1\frac{\partial L_{1r}}{\partial q_r} + I\frac{\partial L_{2r}}{\partial q_r} + \cdots I_r\frac{\partial L_{rr}}{\partial q_r}\right) + \frac{d}{dt}\left(\frac{\partial T_m}{\partial \dot{q}_r}\right) - \frac{\partial T_m}{\partial q_r} = \Phi_r. \tag{23}$$

The part involving T_m is simply the part of Φ_r necessary to accelerate the brute matter of the conductors. In the case where the conductors are held fixed, Φ_r represents what we have called F_r and (23) becomes

$$I_r\left(I_i\frac{\partial L_{ir}}{\partial q_r} + I_2\frac{\partial L_{2r}}{\partial q_r} + \cdots I_r\frac{\partial L_{rr}}{\partial q_r}\right) = F_r, \tag{24}$$

which is the same as our law (18), which is the equivalent of (12).

We may regard the achievement of Maxwell as that of finding the necessary expression for T to permit of the moulding of the equations into the dynamical form in the sense we have described.

Maxwell next endeavored to extend the theory to open circuits, and to the motion of charges. Writing (10) in differential form it becomes

$$4\pi \mathbf{i} = \text{curl } \mathbf{H}, \tag{25}$$

where $\mathbf{i}$ is now the current density, it being understood, however, that the stream lines of the flow continue themselves into a complete circuit.

The thought is that $\mathbf{i}$ may be regarded as a flow of some density with a velocity $\mathbf{u}$, and that we may be able to write

$$\frac{4\pi\rho\mathbf{u}}{c} = \text{curl } \mathbf{H}. \tag{26}$$

The factor c is included because, if ρ is in electrostatic units, our thought of the similarity between what has been called current density and $\rho\mathbf{u}$ has implied only a proportionality between $\rho\mathbf{u}$ and $\mathbf{i}$, since the unit of $\mathbf{i}$ in equation (25) has been chosen so that $\mathbf{H}$ shall represent the force on unit pole in such cases where that test is applicable. c is in fact, the ratio of the electrostatic to the electromagnetic unit of charge.

With equation (26) however, we immediately encounter a difficulty; for, since div. curl $\mathbf{H} = 0$, that equation would imply

$$\text{div. } \rho\mathbf{u} = 0.$$

But, if we are to regard electricity in the light of an indestructible entity, its motion must be controlled by the equation of continuity

$$\text{div. } \rho\mathbf{u} + \frac{\partial\rho}{\partial t} = 0, \tag{27}$$

so that (26) must be regarded as impossible for even such a simple case as that of a moving charge of finite spacial extent, since here the density at any point changes with the time.

In order to escape this difficulty, Maxwell generalized (26), which is strictly true only when $\partial\rho/\partial t = 0$, to the equation

$$\frac{4\pi}{c}(\rho\mathbf{u}) + \frac{1}{c}\frac{\partial\mathbf{E}}{\partial t} = \text{curl } \mathbf{H}, \tag{28}$$

which, on taking the divergence of both sides gives

$$4\pi \text{ div. } \rho\mathbf{u} + \frac{\partial}{\partial t}\text{div. } \mathbf{E} = 0 \tag{29}$$

so that, provided that

$$4\pi\rho = \text{div. } \mathbf{E} \tag{30}$$

(29) becomes

$$\text{div. } (\rho\mathbf{u}) + \frac{\partial\rho}{\partial t} = 0$$

so that the situation is now consistent with the equation of continuity.[6]

The quantity **E** occurring in (30) is of course, measured in electrostatic units, while the **E** in (11) is associated with a current I measured in the same units as are employed in (10). Hence, if **E** is to be in electrostatic units, we must divide the left-hand side of (11) by c; and, expressed in differential form, and applied to a fixed circuit of infinitesimal dimensions, the equation would then become

$$-\frac{1}{c}\frac{\partial\mathbf{H}}{\partial t} = \text{curl } \mathbf{E}. \tag{31}$$

It will here be noted that we have a partial time derivative in place of the total time derivative of (11) which latter equation is applicable to a moving circuit as well as to a fixed one.

Equation (14), with the current (there in electromagnetic units) regarded in the light of a generalization to moving charge density becomes the equivalent of stating that the force per unit volume on the electricity moving with velocity

[6] The generalization on (26) implied in the addition of the term involving $\partial\mathbf{E}/\partial t$, is of course not the only one possible. We might add *in addition* any vector whose divergence was zero without violating (27).

u is $\rho[\mathbf{u}\cdot\mathbf{H}]/c$, the c being introduced because ρ is in electrostatic units. If we introduce the further idea that, in the presence of an electric field **E** there would be a force per unit volume equal to $\mathbf{E}\rho$,[7] $\rho[\mathbf{u}\cdot\mathbf{H}]/c$ the total force per unit charge would be

$$\text{Force per unit charge} = \mathbf{E} + \frac{[\mathbf{uH}]}{c}. \tag{32}$$

If we take a new unit of charge strength and a new unit of magnetic pole strength each respectively $1/\sqrt{4\pi}$ of the electrostatic and magnetostatic units, and if the fields **E** and **H** be defined as the forces on these units, the 4π disappears, as is well known from (28) and (30), and our equations become

$$1/c\left(\rho\mathbf{u} + \frac{\partial\mathbf{E}}{\partial t}\right) = \text{curl } \mathbf{H}, \tag{33}$$

$$\rho = \text{div. } \mathbf{E}, \tag{34}$$

$$-\frac{1}{c}\frac{\partial\mathbf{H}}{\partial t} = \text{curl } \mathbf{E}, \tag{35}$$

$$0 = \text{div. } \mathbf{H}. \tag{36}$$

$$\text{Force per unit charge} = \mathbf{E} + \frac{[\mathbf{uH}]}{c}. \tag{37}$$

The addition of the equations $0 = \text{div. } \mathbf{H}$ implies the additional postulate that all magnetic fields are traceable to currents without the invocation of any magnetic poles.

The foregoing arguments can hardly be regarded as a proof of the relations (33)–(37). As we have already remarked, the generalization involved in the addition of the term involving $\partial\mathbf{E}/\partial t$ in (33) could have been made in an infinite number of other ways as far as serving the purpose of providing for the equation of continuity is concerned. Again, the deduction of (35) as applied to the field at a point in space from the (11) as applied to a complete material circuit is not an entirely rigorous procedure. Similar remarks may

[7] This is not a foregone conclusion, because even in the sense of the definition of **E** in terms of the force on a charge, that charge is supposed at rest.

be made regarding (37). Moreover, the sense in which the term "force" is considered as applying in eqnations (37) is to some extent vague when considered in relation to distributions of electricity, for the scheme of equations itself provides no idea of electric mass to combine with acceleration as a criterion for a realization of the actions of the so-called force.

The best that can be said for the differential forms of the equations in the light in which they have thus been obtained is that they are forms which when applied to the large scale phenomena of wire circuits, reproduce the equations (10) and (11). And even this statement is not correct except for steady currents for equation (10) contains no $\partial\mathbf{E}/\partial t$ term. It is quite true that the scheme represented by (10), (11), and (12), together with its moulding into a dynamical form as carried out by Maxwell represents a logical scheme which might have corresponded to nature even for varying currents. There are no inconsistencies in the scheme itself. The extension to the general case of moving charges has, however, necessitated the introduction of the $\partial\mathbf{E}/\partial t$ term; and, this term having been introduced, it must not be discarded on return to the simpler case of closed circuits unless it, of its own accord, disappears for that case, and this it does not do.

Maxwell was not satisfied with a mere deduction of (35) by the process we have sketched; but, having modified (26) by the introduction of the $\partial\mathbf{E}/\partial t$ term, he proceeded to seek an expression for the kinetic and potential energies per unit volume in terms of the electric fields and the current densities, which, by the application of the dynamical equations for continuous media should result in equations (33)–(37), in a manner analogous to that which he had adopted for the case of continuous circuits. His analysis suffered from certain imperfections, and it was later modified by Lorentz, Larmor, and others, with the special additional postulate that the electricity existed in the form of definite entities or electrons. The procedure amounted to choosing an expression for the kinetic and potential energies per unit volume of the medium as a function of the electric field and motion of the electricity, and then by means of the Hamiltonian dynamical principle

$\delta \int (T - V)dt = 0$ applied to these energy expressions deducing two sets of equations, one of which was the equivalent of (35), and the other the equivalent of (37), but in a more unambiguous form. The form in question stated that the electron moves in such a manner that

$$\iiint \left(\mathbf{E} + \frac{[\mathbf{uH}]}{c} \right) \rho d\tau = 0, \tag{38}$$

the integral being taken over the electron and the fields representing the total fields, including the parts produced by the electron itself.

Again, these derivations can hardly be regarded as having accomplished more than the finding of the expressions which it is appropriate to call kinetic and potential energy in order that the customary dynamical procedure shall lead to the equations desired.

As a matter of fact, the form of the force equation symbolized in (38) is one which would be inconsistent with the principle of relativity; for, in the manner which it is presented by the dynamical development, it is of course not restricted to the case where the electron is momentarily at rest in the system of axes to which **E** and **H** are referred.

We shall presently return to another form of the expression of the dynamics of the electron, and one which is consistent with the theory of relativity; but for the moment, it will be well to make a digression to discuss a few matters concerned with the significance of (1)–(4), quite apart from the question of their origin.

The Significance of the Circuital Relations.—In the first place it is to be remarked that while equations (1)–(4) may be solved so as to give the fields **E** and **H** in terms of ρ and $\rho\mathbf{u}$ supposed assigned, they tell us nothing about the motions of the charges themselves. Since the equations are linear, we may add any two solutions and obtain as a result another solution. Thus, if we should find, as is in fact quite easy to do, the solution for the fields of an electron moving in a straight line with velocity v, and add to this the solution for another electron moving towards the first with velocity v,

and then add the solutions, the result would also satisfy the equations. The equations themselves would be perfectly content for the electrons to go on in their motions quite oblivious of each other's presence. It is to the force equation entirely that we must look for an answer to how the motions of the electron influence each other. Had equations (1)–(4) been non-linear, this conclusion would not have held, solutions would not have been additive to give another solution; and, the equations themselves would have had something to say about the motions of the electrons relative to each other.

We frequently hear difficulties raised as to how the electron holds together, in view of the repulsion of its individual parts. Logically there is no difficulty. Equations (1)–(4) are perfectly content to have the various parts of an electron in mutual proximity without any tendency to fly apart. Even the force equations concern only the motion of the electron as a whole; and it is no quibble to maintain that the ideas applicable to the whole entity are not applicable to its individual parts; for, as a matter of fact, even equation (38) while implying a motion of the electron which secures a zero value for $\iiint (\mathbf{E} + [\mathbf{uH}]/c)\rho d\tau$, by no means provides for the vector $\mathbf{E} + [\mathbf{uH}]/c$ being zero at each element of volume.

Solution of the Equations.—It is possible to solve equations (1)–(4) in such manner as to obtain the field $\mathbf{E}$, $\mathbf{H}$, in terms of the charge density ρ, and the product $\rho\mathbf{u}$ supposed assigned. The results are:

$$\mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{U}}{\partial t} - \text{grad. } \varphi, \tag{39}$$

$$\mathbf{H} = \text{curl } \mathbf{U}, \tag{40}$$

where

$$4\pi c\mathbf{U} = \iiint \frac{(\rho\mathbf{u})}{r}\, d\tau, \tag{41}$$

$$4\pi\varphi = \iiint \frac{(\rho)}{r}\, d\tau, \tag{42}$$

and where $\mathbf{U}$ and φ are still further subjected to the condition

that

$$\text{div. } \mathbf{U} = -\frac{1}{c}\frac{\partial \varphi}{\partial t}. \tag{43}$$

The integrals are supposed taken throughout all space, and the parentheses are intended to denote that in finding the values of $\mathbf{U}$ and φ at time t, at any point (which is momentarily taken as the origin) we must insert in any particular element of volume the values of ρu or ρ not at the time t, but at the earlier time $t - r/c$.[8]

Equations (1) and (2) of course contain the equation of continuity as a consequence. It can readily be shown that the relation (43) is the analytical guardian of the equation of continuity in preventing us from assigning in (41) and (42), values of $\rho\mathbf{u}$ and ρ which would of themselves violate that condition.

Thus, for example, if we were to assign $\mathbf{u} = 0$, and $\rho = f(r)e^{-\alpha t}$, our assignment would of itself be inconsistent with

$$\text{div. } \rho\mathbf{u} + \frac{\partial \rho}{\partial t} = 0.$$

Equations (43) would prevent such an assignment of ρ and $\rho\mathbf{u}$.

The fact that the solutions represent φ and $\mathbf{U}$ and so $\mathbf{E}$ and $\mathbf{H}$ as the sum of a number of parts, each determined independently by the separate elements of charge enables us to speak of the field contributed by a charge A as distinct from the field contributed by some other charge B. Had, for example, products of the values of $\rho\mathbf{u}$ in the different elements of volume been involved in the expression for the field at a point, it would have been impossible to speak of a part of the field being due to one charge and part to another.

Definitions.—Before proceeding further, it is well that we pause for a moment to consider the significance which is to be attached to quantities like $\mathbf{E}$ and $\mathbf{H}$ in a scale of analysis which is contemplated in the equations as they are used in atomic physics. The definition of the magnetic field as the force on a unit magnetic pole, and of the electric field as the

[8] We shall not pause to consider the possibilities inherent in the use of the advanced potentials.

force on unit charge, are permissible so long as we are dealing with large scale phenomena; but, a unit pole has only existence in a macroscopic sense where a point is identified in a crude way with a region sufficiently large to contain many molecules. Even though, in the case of the charge, we can go to as small a unit as the electron, at any rate in imagination, for a charge entity in terms of which to define, by the magnitude of its acceleration, the electric field, our procedure becomes illogical when we contemplate a situation in which the field **E** varies enormously in magnitude and direction over the space comprised by a single electron. The question here involved is not one of experimental difficulty, but of logical meaninglessness. It is not one purely ideal in its character, moreover; for in one of the most important applications of the equations, that involved in finding the quantity represented by the right-hand side of (6), we encounter a situation in which the quantity **E** with which we deal, varies to the extent of the whole of its value over the electron.

Why is it that we are not led into hopeless error in cases of the above kind? It is because we do not *use* **E** and **H** in the sense of the definition in terms of unit charges and unit magnetic poles.

If we examine what we actually do in all problems of atomic dimensions, we shall find that the starting point is the *assignment* of the charges and of their motions—the assignment of ρ and $\rho\mathbf{u}$. This is followed by the *calculation* of **E** and **H** by aid of equations (39)–(42), and the subsequent utilization of the same **E** and **H** for some specific purpose, as, for example, the determination of the integral on the right-hand side of (6) (where only **E** is required however).

From the standpoint which is the standpoint of their actual use in nearly all problems of atomic importance, equations (1)–(4) really constitute the *definitions* of **E** and **H** in terms of ρ and $\rho\mathbf{u}$ supposed assigned.

But you may well ask what we gain by mere definition. We cannot discover laws of physics by definitions. That is true; but, we can, by well chosen definitions insure useful properties for the quantities defined. Thus, the quantities **E** and **H** defined by equations (1)–(4) vary with space and

time in free space in accordance with the wave equations. Thus, for example:

$$\nabla^2\mathbf{E} - \frac{1}{c^2}\frac{\partial^2\mathbf{E}}{\partial t^2} = 0$$

and the wave equation insures for them certain other important properties—such, for example, as the property that in a plane wave the vectors **E** and **H** are perpendicular to each other, and lie on the plane of the wave-front. It would be useless to define things like **E** and **H** if we could not express in terms of them the behavior of something we can observe. The justification for their definition in electrodynamics lies in their being appropriate quantities in terms of which to express the motions of electrons through such equations as (6), or (9), for example; and, the properties provided for in their definitions provide in turn for properties which we can observe in the motions of the electrons referred to. Now it is quite true that, in the majority of problems of atomic dynamics, the things which happen to electrons do not go on in such manner as to indicate that they have been controlled by the force equation. Nevertheless, in formulating the new laws of such a phenomenon as the photoelectric effect, for example, the properties of **E** and **H** inherent in their definitions through the electromagnetic equations make them useful props in a scaffolding appropriate to the new theory.

All that we need as a basis in terms of which to define a set of electromagnetic vectors satisfying equations (1)–(4) is a quantity ρ and a quantity $\rho\mathbf{u}$ satisfying the equation of continuity

$$\text{div. } \rho\mathbf{u} + \frac{\partial\rho}{\partial t} = 0.$$

As a matter of fact, the density and density times velocity occur in the solutions for φ and **U**, and so in those for **E** and **H** in the forms they do, not because of any property inherent in themselves, but simply on account of their relative positions in (1)–(4). If we should replace ρu_x, ρu_y, ρu_z, ρ by any four quantities $\mathbf{S}_x$, $\mathbf{S}_y$, $\mathbf{S}_z$, $\mathbf{R}$, satisfying

$$\text{div. } \mathbf{S} + \frac{\partial\mathbf{R}}{\partial t} = 0,$$

the solutions would be of exactly the same form as before, with $\mathbf{S}$ and $\mathbf{R}$ replacing $\rho\mathbf{u}$ and ρ.

In Schrödinger's theory of atomic structure, at any rate in its original aspect in which he seeks to account for the frequencies emitted by an atom, the aim is to get a quantity which he calls $\psi\bar{\psi}$, varying with x, y, z, and varying everywhere with time in a manner composed of the simple harmonic frequencies desired. The nature of $\psi\bar{\psi}$ turns out to be such that when integrated throughout space, the result is constant with time. Hence, defining $\mathbf{u}$ by the relation

$$\psi\bar{\psi}\cdot\mathbf{u} = -\frac{1}{4\pi}\,\text{grad}\iiint\frac{1}{r}\cdot\frac{\partial\psi\bar{\psi}}{\partial t}d\tau,$$

we insure that

$$\text{div.}\,(\psi\bar{\psi}\cdot\mathbf{u}) + \frac{\partial\psi\bar{\psi}}{\partial t} = 0, \tag{44}$$

so that $\psi\bar{\psi}$ satisfies the equation of continuity. Moreover, integrating throughout space

$$\begin{aligned}\partial/\partial t\iiint\psi\bar{\psi}d\tau &= -\iiint\text{div.}\,\psi\bar{\psi}\mathbf{u}d\tau\\ &= -\iint\psi\bar{\psi}u_n dS,\end{aligned} \tag{45}$$

the surface being supposed at infinity.

Since $\iiint\psi\bar{\psi}d\tau$ is constant, $\iint\psi\bar{\psi}\mathbf{u}_n dS = 0$. Had this not been the case, our adjustment of $\mathbf{u}$ to satisfy (44) would have involved us in a flow through the infinite boundary, a circumstance which would have involved us in logical difficulties into which we need not enter further here.

The equation of continuity having been provided for, the quantities $\psi\bar{\psi}$ and $\psi\bar{\psi}\cdot u$ provide suitable quantities in terms of which to define a set of vectors $\mathbf{E}$ and $\mathbf{H}$, satisfying equations of the type (1)–(4), in terms of which the action of radiation on some other atom may be discussed.

By proceeding to the limiting case for a doublet M in electromagnetic theory, we find that φ and $\mathbf{U}$, and so $\mathbf{E}$ and $\mathbf{H}$ are completely determined by the assignment of $\mathbf{M}$ and $\dot{\mathbf{M}}$, so that any quantity $\mathbf{M}$ varying with time and assigned

to a particular point of space may be used as a basis for defining a set of electromagnetic vectors conforming to the frequencies contained in the time variations in **M**. In some cases of modern atomic theory where there are several dimensions, the nature of the $\psi\bar{\psi}$ function referred to above is such that the quantity is expressed as a function of more than 3 coördinates, and consequently it cannot immediately be assigned to any particular point in space. Nevertheless, the process adopted in integrating throughout the multi-dimensional space for the purpose of finding what Schrödinger refers to as the moment, does lead to a definite number for the atom, a number, moreover, having in its time variations the frequencies desired; and, this number with its time rate of change may be used as a means of defining a set of electromagnetic vectors as before. The argument in the multi-dimensional space assigns no position to this moment in the multidimensional space, but on the other hand, it has no power to prevent our assigning to it any position we choose.

It is true that, in the more recent developments of Heisenberg and others, we have come to regard the $\psi\bar{\psi}$ function in a light different from that implied above. Nevertheless, the illustration we have given serves to indicate the sort of position which the electromagnetic equations may occupy in developments of modern atomic dynamics.

The vectors **E** and **H** having been provided for in some such manner as the foregoing, we may then proceed to calculate their values at other points in space where we wish to discuss some phenomenon such as the Compton effect, for example. It is then in terms of these vectors **E** and **H**, that we discuss the phenomenon; not by their action in the sense of the old force equation of electrodynamics, but usually in their modification of some Hamiltonian form which is to be used as the basis of the theory under consideration.

Definitions in Terms of Assigned Entities.—For one to whom the aspect of (1)–(4) as definitions of **E** and **H** is too artificial for his mental satisfaction, and who insists upon definitions of **E** and **H** in terms of the supposed action of these vectors on something or other, a way is still open, at least to a scale of precision which regards the electron as no more than a point entity. It is only at the expense of

considerable complication, however, that this way can be made precise.

The most drastic change from the classical procedure must be made in the matter of the magnetic pole. And, as is often the case, if we follow the plan of what actually happens in nature rather than invent artificial concepts, we gain in the long run. The action of a magnetic field on a pole is an idealization of its action on a magnet, and that is an idealization of the really more simple concept of its action on a moving electron, since the motions of electrons endow the magnet with its magnetic properties. It is then in the spirit of its action on a moving electron that we shall seek to define our magnetic field.

Let us suppose for a moment, that **E** and **H** had been defined in a manner which for the moment we need not specify, and let us suppose that the motion of an electron in terms of the fields so defined were given by (9), where we shall suppose the terms on the right-hand side other than the first to be absent. Then, by putting $w = 0$, it would be a fact that

$$\mathbf{E}_0 = \frac{m_0}{e} \underset{w=0}{L_t} \frac{d}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \tag{46}$$

and that when w was not zero,

$$\frac{[\mathbf{w}\mathbf{H}_0]}{c} = \frac{m_0}{e} \left\{ \left(\frac{d}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \right)_{w \neq 0} - \underset{w=0}{L_t} \frac{dt}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \right\}. \tag{47}$$

If the direction of **w** be adjusted so that the quantity on the right-hand side is a maximum, we shall have

$$\frac{\mathbf{H}_0}{c} = \frac{m_0}{ew} \left\{ \left(\frac{d}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \right)_{w \neq 0} - \underset{w=0}{L_t} \frac{d}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \right\}, \tag{48}$$

where the **w** inserted is chosen in the direction to make $\mathbf{H}_0$ a maximum. The direction of $\mathbf{H}_0$ is that consistent with the vector product of $\mathbf{H}_0$ and the velocity **w** being in the direction of the vector specified as the right-hand side of (47).

Now the facts embodied in the above equations provide us with a means of defining $\mathbf{E}_0$ and $\mathbf{H}_0$. For, suppose,

discarding the fact that $\mathbf{E}_0$ and $\mathbf{H}_0$ were supposed defined originally, we take (46) as a definition of $\mathbf{E}_0$; and, after proceeding to the limit when $w = 0$ in order to secure uniqueness, suppose we take (48) as the basis of our definition of $\mathbf{H}_0$. That is:

$$\frac{\mathbf{H}_0}{c} = \frac{m_0}{e} \underset{w=0}{L_t} \frac{\left[\left(\dfrac{d}{dt}\dfrac{\mathbf{w}}{\sqrt{1 - w^2/c^2}}\right)_{w\neq 0} - \underset{w=0}{L_t}\dfrac{d}{dt}\dfrac{\mathbf{w}}{\sqrt{1 - w^2/c^2}}\right]}{w}. \tag{49}$$

Then, the definitions so found will be consistent with the equation

$$e\left(\mathbf{E}_0 + \frac{[\mathbf{w}\mathbf{H}_0]}{c}\right) = \frac{d}{dt}\frac{m_0\mathbf{w}}{\sqrt{1 - w^2/c^2}} \tag{50}$$

for all values of $\mathbf{w}$. Of course, they would not *necessitate* that (50) should hold for all values of $\mathbf{w}$.

If it did not turn out that (50) were true for all values of $\mathbf{w}$ when $\mathbf{E}_0$ and $\mathbf{H}_0$ were defined in terms of its limiting value, our definitions would be definite, at least, apart from further criticisms which I shall presently raise, but they would be useless. It would then be necessary to find in place of $\dfrac{d}{dt}\dfrac{m_0\mathbf{w}}{\sqrt{1 - w^2/c^2}}$ a quantity $\mathbf{W}$ which, when we again made our definitions in a manner analogous to the above, gave us quantities $\mathbf{E}_0$ and $\mathbf{H}_0$, which were consistent with

$$e\left(\mathbf{E}_0 + \frac{[\mathbf{w}\mathbf{H}_0]}{c}\right) = \mathbf{W} \tag{51}$$

for all values of $\mathbf{w}$.

Of course, it will be understood that our experimental realization of the above definitions would involve the measurement of such quantities as $\underset{w=0}{L_t}\dfrac{d}{dt}\dfrac{\mathbf{w}}{\sqrt{1 - w^2/c^2}}$, a more or less ideal experiment. In the case cited, we should have nothing but an acceleration to measure; but in general, this would not be the case. Thus, to take an example, suppose there existed certain quantities $\mathbf{E}_0$ and $\mathbf{H}_0$ in terms of which the equation of motion of the electron was

$$e\left(E_0 + \frac{[\mathbf{w}\mathbf{H}_0]}{c}\right) = a_0\ddot{\mathbf{S}} + a_1\dddot{\mathbf{S}} + a_2\ddddot{\mathbf{S}} + \cdots, \tag{52}$$

considerable complication, however, that this way can be made precise.

The most drastic change from the classical procedure must be made in the matter of the magnetic pole. And, as is often the case, if we follow the plan of what actually happens in nature rather than invent artificial concepts, we gain in the long run. The action of a magnetic field on a pole is an idealization of its action on a magnet, and that is an idealization of the really more simple concept of its action on a moving electron, since the motions of electrons endow the magnet with its magnetic properties. It is then in the spirit of its action on a moving electron that we shall seek to define our magnetic field.

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and that when w was not zero,

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If the direction of **w** be adjusted so that the quantity on the right-hand side is a maximum, we shall have

$$\frac{\mathbf{H}_0}{c} = \frac{m_0}{ew} \left\{ \left(\frac{d}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \right)_{w \neq 0} - \underset{w=0}{L_t} \frac{d}{dt} \frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}} \right\}, \tag{48}$$

where the **w** inserted is chosen in the direction to make $\mathbf{H}_0$ a maximum. The direction of $\mathbf{H}_0$ is that consistent with the vector product of $\mathbf{H}_0$ and the velocity **w** being in the direction of the vector specified as the right-hand side of (47).

Now the facts embodied in the above equations provide us with a means of defining $\mathbf{E}_0$ and $\mathbf{H}_0$. For, suppose,

discarding the fact that $\mathbf{E}_0$ and $\mathbf{H}_0$ were supposed defined originally, we take (46) as a definition of $\mathbf{E}_0$; and, after proceeding to the limit when $w = 0$ in order to secure uniqueness, suppose we take (48) as the basis of our definition of $\mathbf{H}_0$. That is:

$$\frac{\mathbf{H}_0}{c} = \frac{m_0}{e} \underset{w=0}{L_t} \frac{\left[\left(\frac{d}{dt}\frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}}\right)_{w \neq 0} - \underset{w=0}{L_t}\frac{d}{dt}\frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}}\right]}{w}. \quad (49)$$

Then, the definitions so found will be consistent with the equation

$$e\left(\mathbf{E}_0 + \frac{[\mathbf{w}\mathbf{H}_0]}{c}\right) = \frac{d}{dt}\frac{m_0\mathbf{w}}{\sqrt{1 - w^2/c^2}} \quad (50)$$

for all values of $\mathbf{w}$. Of course, they would not *necessitate* that (50) should hold for all values of $\mathbf{w}$.

If it did not turn out that (50) were true for all values of $\mathbf{w}$ when $\mathbf{E}_0$ and $\mathbf{H}_0$ were defined in terms of its limiting value, our definitions would be definite, at least, apart from further criticisms which I shall presently raise, but they would be useless. It would then be necessary to find in place of $\frac{d}{dt}\frac{m_0\mathbf{w}}{\sqrt{1 - w^2/c^2}}$ a quantity $\mathbf{W}$ which, when we again made our definitions in a manner analogous to the above, gave us quantities $\mathbf{E}_0$ and $\mathbf{H}_0$, which were consistent with

$$e\left(\mathbf{E}_0 + \frac{[\mathbf{w}\mathbf{H}_0]}{c}\right) = \mathbf{W} \quad (51)$$

for all values of $\mathbf{w}$.

Of course, it will be understood that our experimental realization of the above definitions would involve the measurement of such quantities as $\underset{w=0}{L_t}\frac{d}{dt}\frac{\mathbf{w}}{\sqrt{1 - w^2/c^2}}$, a more or less ideal experiment. In the case cited, we should have nothing but an acceleration to measure; but in general, this would not be the case. Thus, to take an example, suppose there existed certain quantities $\mathbf{E}_0$ and $\mathbf{H}_0$ in terms of which the equation of motion of the electron was

$$e\left(E_0 + \frac{[\mathbf{w}\mathbf{H}_0]}{c}\right) = a_0\ddot{\mathbf{S}} + a_1\dddot{\mathbf{S}} + a_2\ddddot{\mathbf{S}} + \cdots, \quad (52)$$

where $\ddot{\mathbf{S}}$ represents the acceleration, and the a's are functions of the velocity. On putting $\mathbf{w} = 0$, we obtain

$$e\mathbf{E}_0 = \bar{a}_0\ddot{\mathbf{S}} + \bar{a}_1\dddot{\mathbf{S}} + \bar{a}_2\ddddot{\mathbf{S}} + \cdots, \tag{53}$$

where the $\bar{a}$'s are the limiting values of the a's for zero velocity. We see that, in order to complete our definition it would be necessary to specify $\dddot{\mathbf{S}}, \ddddot{\mathbf{S}}, \cdots$, etc., when $w = 0$. Moreover, we cannot specify these arbitrarily. For example, we cannot say "consider an electron for which the velocity is zero and all the time derivatives of the motion are zero except $\ddot{\mathbf{S}}$, because, although $\ddot{\mathbf{S}}$ could adjust itself so that $e\mathbf{E}_0 = \bar{a}_0\ddot{\mathbf{S}}$ at the instant chosen, it would have to be in the process of change in order to make (52) fit the possibly new value of $\mathbf{E}_0$, and of $\mathbf{H}_0$ and $\mathbf{w}$ at the next and subsequent instants. Our only hope, in the case of such a situation as is represented in (53) would be, having made a satisfactory guess at the final form (52), to proceed to its limiting case (53), and then define $\mathbf{E}_0$ in terms of the actual values of $\ddot{S}$, $\dddot{S}$, etc., as measured for that case.[9]

The Relativity Dynamics of the Electron.—Although the recent developments of the quantum theory have rendered it necessary for us to change our ideas as to the motion of an electron, and to discard completely the older force equations of electrodynamics as representative of the laws of motion of the electron, nevertheless the fact that classical laws do hold in limiting cases of slowly varying forces causes them still to form an important part in the dynamic story of atomic processes. And, possibly on account of the primitive stages of development of the modern theories, certain of the expressions of classical theory do play a part, and an important part, in building up the detailed laws of quantum mechanics.

In our modern representation of the classical theory we pay little attention to such concepts as the electrons moving in such a way as to satisfy (38), but place more weight on the relativity theory as a guide.

[9] Even here, it is not obvious that there would be a unique set of values of the time derivatives of S for a given value of $\mathbf{E}_0$, independently of the way in which $\mathbf{E}_0$ was changing with the time. However, we here enter upon the whole question of the possibility of an expression of the type (52) as representing the motion of an electron.

In ordinary general dynamics, the equation of motion of a system may be written in the form of Lagrange's equation

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_r}\right) - \frac{\partial L}{\partial q_r} = 0. \tag{54}$$

Here no restriction is placed on L, other than the restriction that it is a function of the coördinates and the generalized velocities, and possibly also of the time. (54) is the analytical equivalent of

$$\delta \int L dt = 0, \tag{55}$$

where the values of δq_r at the time limits are zero. (54) contains as a consequence

$$\frac{d}{dt}\left\{\Sigma \dot{q}_r \frac{\partial L}{\partial \dot{q}_r} - L\right\} + \frac{\partial L}{\partial t} = 0. \tag{56}$$

If $L = T - V$ and T is a homogeneous quadratic function of the time rates of change of the coördinates, while V is a function of the coördinates and time, it is easy to show that

$$\Sigma \dot{q}_r \frac{\partial L}{\partial \dot{q}_r} = 2T$$

and equation (56) becomes

$$\frac{d}{dt}(T + V) + \frac{\partial L}{\partial t} = 0,$$

so that if V does not involve the time explicitly

$$\frac{d}{dt}(T + V) = 0$$

and

$$T + V = \text{constant}$$

$T + V$ is of course the energy. Even where L is not of the above form, however, it is still true that if L does not involve t explicitly, $\Sigma \dot{q}_r(\partial L/\partial \dot{q}_r) - L$ is constant with time, so it is convenient to give the name energy to this quantity for the general case

$$\text{Energy} = \Sigma \dot{q}_r \frac{\partial L}{\partial \dot{q}_r} - L$$

where $\ddot{\mathbf{S}}$ represents the acceleration, and the a's are functions of the velocity. On putting $\mathbf{w} = 0$, we obtain

$$e\mathbf{E}_0 = \bar{a}_0\ddot{\mathbf{S}} + \bar{a}_1\dddot{\mathbf{S}} + \bar{a}_2\ddddot{\mathbf{S}} + \cdots, \tag{53}$$

where the $\bar{a}$'s are the limiting values of the a's for zero velocity. We see that, in order to complete our definition it would be necessary to specify $\dddot{\mathbf{S}}, \ddddot{\mathbf{S}}, \cdots$, etc., when $w = 0$. Moreover, we cannot specify these arbitrarily. For example, we cannot say "consider an electron for which the velocity is zero and all the time derivatives of the motion are zero except $\ddot{\mathbf{S}}$, because, although $\ddot{\mathbf{S}}$ could adjust itself so that $e\mathbf{E}_0 = \bar{a}_0\ddot{\mathbf{S}}$ at the instant chosen, it would have to be in the process of change in order to make (52) fit the possibly new value of $\mathbf{E}_0$, and of $\mathbf{H}_0$ and $\mathbf{w}$ at the next and subsequent instants. Our only hope, in the case of such a situation as is represented in (53) would be, having made a satisfactory guess at the final form (52), to proceed to its limiting case (53), and then define $\mathbf{E}_0$ in terms of the actual values of $\ddot{S}$, $\dddot{S}$, etc., as measured for that case.[9]

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$$\frac{d}{dt}\left\{ \Sigma \dot{q}_r \frac{\partial L}{\partial \dot{q}_r} - L \right\} + \frac{\partial L}{\partial t} = 0. \tag{56}$$

If $L = T - V$ and T is a homogeneous quadratic function of the time rates of change of the coördinates, while V is a function of the coördinates and time, it is easy to show that

$$\Sigma \dot{q}_r \frac{\partial L}{\partial \dot{q}_r} = 2T$$

and equation (56) becomes

$$\frac{d}{dt}(T + V) + \frac{\partial L}{\partial t} = 0,$$

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and understand by this the energy even for cases where L does involve t explicitly. An analytical equivalent of (54) or (55) is

$$\dot{q}_r = \frac{\partial H}{\partial p_r}; \qquad \dot{p}_r = -\frac{\partial H}{\partial p_r}, \tag{57}$$

where p_r is defined as

$$p_r \equiv \frac{\partial L}{\partial \dot{q}_r} \tag{58}$$

and H is defined as

$$H \equiv \Sigma p_r \dot{q}_r - L, \tag{59}$$

where, however, the $\dot{q}$'s in H are expressed in terms of the q's and p's through equations (58), so that H is a function of the p's and q's and of t.

It is an analytical consequence of (57) that

$$\frac{dH}{dt} = -\left(\frac{\partial L}{\partial t}\right) p\text{'s and } q\text{'s constant.} \tag{60}$$

Again, if $L = T - V$ and T is a homogeneous quadratic function of the velocities and V a function of coördinates and time, $H = T + V$, and is constant with time if L does not involve t explicitly.

In general, if

$$L = T' - V,$$

where T' is merely a function of velocities, coördinates and time, but not a homogeneous quadratic function, the energy $\Sigma p_r \dot{q}_r - L$ will be something other than $T' + V$, and it will be this something which will be constant with time or equal to $-(\partial L/\partial t)$ according as L does or does not involve t explicitly.

Thus, suppose for an assemblage of electrons

$$L = \Sigma_i - m_{0i}c^2\sqrt{1 - \beta_i^2} - e\varphi_i + \frac{e}{c}(U_{xi}u_{xi} + U_{yi}u_{yi} + U_{zi}u_{zi}), \tag{61}$$

where

$$c^2\beta^2 = u_x^2 + u_y^2 + u_z^2$$

and where, in considering the values of U_i and φ_i, we consider only the contributions from charges other than the electron denoted by the subscript i. The quantity L satisfies the requirements we have imposed on L, the requirements of being a function of the q's, the $\dot{q}$'s and t.[10] Equation (58) then leads to

$$\mathbf{p}_i = \frac{m_{0i}\mathbf{u}_i}{\sqrt{1 - \beta_i^2}} + \frac{e}{c}\mathbf{U}_i. \tag{62}$$

On making use of this in (59) we find

$$H \equiv \Sigma_r p_r \dot{q}_r - L = \Sigma_i \left\{ \frac{m_{0i}c^2}{\sqrt{1 - \beta_i^2}} + e\varphi_i \right\}, \tag{63}$$

so that if the φ_i and $\mathbf{U}_i$ are independent of t explicitly, so that L is independent of t explicitly

$$\Sigma_i \left\{ \frac{m_{0i}c^2}{\sqrt{1 - \beta_i^2}} + e\varphi_i \right\} = \text{constant}.$$

Whether this quantity is constant with time or not, it is, as we have remarked, what we call the energy, since it is the quantity which is constant when L is independent of t explicitly.

In the case of a single electron and an external field specified by φ_i and $\mathbf{U}_i$, as functions of position and time, φ_i involves only the coördinates and time, so that it is appropriate to call $e\varphi_i$ the potential energy. It is then appropriate to call $m_{0i}c^2/\sqrt{1 - \beta^2{}_i}$ the kinetic energy T. Or since it is customary to regard T as zero when β is zero, we take

$$T \equiv m_i c^2 \left(\frac{1}{\sqrt{1 - \beta^2{}_i}} - 1 \right)$$

[10] Strictly speaking, the conclusion is not true for $\mathbf{U}$ and φ involve the values of the velocities at retarded times, and when these are expressed in terms of instantaneous values all the higher time derivatives come in. This point does not seem to be taken into account as a rule. It usually causes no harm since the case concerned is usually that of a single electron and $\mathbf{U}$ and φ are then expressed as solutions of the wave equation and regarded as having origin in some other system which is unaffected by the electron. Expressed in this way, they occur simply as functions of the coördinates of the electron i and of the time.

the addition of the constant term does not, of course, affect the condition

$$\frac{d}{dt}(T + V) = -\frac{\partial L}{\partial t},$$

The quantity we have called T' is, in the present case,

$$T' = -m_{0i}c^2\sqrt{1 - \beta_1^2}.$$

Whether φ_i and $\mathbf{U}_i$ are, or are not, independent of t explicitly, it results on applying (54) or (55) to L, that

$$-\frac{1}{c}\frac{\partial \mathbf{U}_i}{\partial t} - \text{grad } \varphi_i + \frac{1}{c}[\mathbf{u}_i \text{ curl } \mathbf{U}_i] = \frac{d}{dt}\left(\frac{m_{0i}\mathbf{u}_i}{\sqrt{1 - \beta_i^2}}\right), \tag{64}$$

so that from (39) and (40)

$$\left(\mathbf{E}_{0i} + \frac{[\mathbf{u}_i\mathbf{H}_{0i}]}{c}\right)e = m_{0i}\frac{d}{dt}\left\{\frac{u_i}{\sqrt{1 - \beta_i^2}}\right\}. \tag{65}$$

Thus we may regard (61) as the appropriate expression for L in order to give rise to the equations of motion (65) by the usual dynamical procedure. In (64) we should regard $\mathbf{U}_i$ and φ_i as defined in terms of the charges of the system by (41) and (42). The quantities $\mathbf{E}_{0i}$ and $\mathbf{H}_{0i}$ need never be used at all except in the light of a shorthand notation. If they are introduced as a matter of convenience, they must be regarded in the light of being defined by (39) and (40); and, in the light of this definition, their obedience to (1)–(4) is guaranteed. We have to choose our Lagrangian function L in any case; and, having chosen it in terms of φ and $\mathbf{U}$, the complete story is told in a way which is definite. It may be wrong, but it is definite, and $\mathbf{E}_{0i}$ and $\mathbf{H}_{0i}$ need never make their appearance at all except in the character of a scaffolding. It is of interest to note that the quantity which we usually call the momentum of an electron i, viz.: $m_{0i}\mathbf{u}_i/\sqrt{1 - \beta_i^2}$ is not the same thing as the generalized momentum of the system *associated* with the electron i, the latter quantity is given by (62).

It is perhaps worth while to emphasize that the application of (54) or (55) to (61) to obtain (64) or (65) is not to be

regarded as a proof of (64) or (65), since the choice of (61) rests on its being the suitable function for this purpose. All that is shown is that (64) or (65) is the analytical equivalent of applying (54) or (55) to (61). Indeed, it is probable that most so-called proofs in physics should be regarded more in the light of showing the analytical equivalence of different statements of a law.

We know that, with suitable definitions of the quantities concerned, (65) is invariant under the restricted relativity transformation. We should expect that this would be the case if Ldt were invariant in form under the Lorentzian transformation. It is easy to see that this invariance holds. For, writing $k_i \equiv (1 - \beta_i^2)^{-1/2}$, dt/k_i is known to be an invariant. Also, $k_{xi}u_{xi}$, $k_{yi}u_{yi}$, $k_{zi}u_{zi}$, $kc\sqrt{-1}$ is a 4-vector. It is the velocity 4-vector. Also

$$U_{xi},\ U_{yi},\ U_{zi},\ \varphi\sqrt{-1} \text{ is a 4-vector.}$$

Thus $m_{0i}c^2\sqrt{1 - \beta_i^2}dt = moc^2 dt/k_i$ and is invariant. Also

$$U_{xi}u_{xi} + U_{yi}u_{yi} + U_{zi}u_{zi} - c\varphi_i$$
$$= (U_{xi}k_iu_{xi} + U_{yi}k_iu_{yi} + U_{zi}k_iu_{zi} - ck_i\varphi_i)\frac{dt}{k_i}$$

and is therefore invariant. Hence, Ldt is invariant.

It is, of course, possible to deduce (65) from the Hamiltonian equations (57). For this purpose we need the Hamiltonian function for an electron. This is to be obtained by substituting for the $\dot{q}$'s in (59) their values in terms of the q's and p's from (62). In this way we readily obtain for a single electron

$$H = c\left[\left(p_x - \frac{e}{c}U_x\right)^2 + \left(p_y - \frac{e}{c}U_y\right)^2 + \left(p_z - \frac{e}{c}U_z\right)^2 + m_0^2c^2\right]^{1/2} + e\varphi.$$

The Magnetic Susceptibility of Aluminium. C. CHÉNEVEAU. (*Comptes Rendus*, April 23, 1928.) Two specimens were tried in the magnetic balance and found to have as their susceptibilities per gram 0.585 and 0.579 $\times 10^{-6}$ respectively. They were prepared by Hoopes' process and had the following composition by per cent., Al, 99.87; Fe, .06; Si, .03; Cu, .04. In shaping the specimens traces of iron were left on their surfaces. The effects of these had to be eliminated. Owen in his determination of the susceptibility of aluminium used metal containing .15 per cent. iron and got a value of .62 $\times 10^{-6}$ and Honda's aluminium had an iron content of .24 per cent. and gave a value of .65 $\times 10^{-6}$. The author measured the susceptibility of aluminium wire containing .5 per cent. iron and got a mean value of .59 $\times 10^{-6}$ that scarcely differed from his previous result when greater precautions were taken. Had the contained iron alone been present and acted magnetically as normal metallic iron its effects would have exceeded the capacity of the magnetic balance. If the iron present were in the condition of ions it by itself should make the susceptibility to be more than three times as great as the value found for the aluminium specimen. A comparison of the values obtained by others with the iron content of their aluminium leads to the conclusion that "small quantities of iron alloyed with aluminium in general change very little the magnetic properties of the latter. The iron seems to act quite differently from its behavior in the metallic or ionic states, its magnetic qualities being considerably reduced as is the case in certain other alloys." G. F. S.

R. A. MILLIKAN and his coadjutors have continued to investigate the extraction of electrons from metals in high vacuum by the action of electric fields. (*Phys. Rev.*, May, 1928.) It takes a field of more than 2,000,000 volts per cm. to cause the smallest current they could accurately measure to flow from platinum whereas less than half of that field strength sufficed to pull the same current from a tungsten point.

In the experiments just mentioned the metal was the cathode. When it was made the anode no current at all was obtained when 100,000 volts was applied from a direct current generator. The field corresponding to this amounted to 35,000,000 volts per cm. Here is a sharp contrast between the behaviors of the two kinds of electricity. G. F. S.

THE PROBLEM OF ARSENICAL SPRAY RESIDUE.*

BY

HOWARD W. AMBRUSTER.

THE seemingly insurmountable obstacle now confronting those who, for commercial or scientific reasons, desire to continue the extensive use of arsenic and other stomach poisons for agricultural insect control, is summed up in a recent address by Dr. A. J. Carlson of the Hull Physiological Laboratory of the University of Chicago.[1] Dr. Carlson discusses the many phases of modern man-made environment from the viewpoint of scientific and medical research and concludes with this rather distressing query, "Are the ablest, the strongest, the wisest men merely grave diggers in disguise?"

Of the so-called "spray-residue" problem he says: "Lead and arsenic are taken into our system with the apple and the pear. We may not consume enough lead and arsenic in our fruit to produce acute poisoning and tissue injury, but who is there to say that this slow assimilation of metallic poisons brought about by modern industry is without danger and ultimate injury? The only factor of safety that I can see in this situation is the phenomenon of tolerance, that is, the capacity of the living organism, if it is not seriously wrecked by the poisons, to so adjust the internal processes as to render the poisons less and less injurious."

Again, in discussing tests on another problem involving foodstuffs Dr. Carlson stated: "It would seem a safer principle for governments and society to insist that the burden of proof of harmlessness falls on the manufacturer or the introducer of new food substitutes rather than on society, and the tests of the harmfulness or harmlessness should involve all the physiological processes of man."

For many years there has been abundant evidence available for those who have studied the subject that the increasing use of arsenic and other stomach poisons for agricultural insect

* Address at 75th Meeting of American Chemical Society, St. Louis, Mo., April, 1928.

[1] Address at Race Betterment Conference, Battle Creek, Mich, Jan. 1928, pub. in *Science*, Vol. LXVII, no. 1736.

control would ultimately result in a conflict between two scientific groups, the entomologists and the health authorities. And it has been equally obvious that as far as the general public was concerned, the entomologists would have no convincing arguments to put forth in meeting objections from health officials to the use of poisons on foodstuffs.

As the concrete problem has developed the sound of the word "arsenic" to the lay mind is the greatest menace in the whole situation. But it is the lead in lead arsenate which carries the greatest actual danger to the public health. Yet paradoxically the lay mind is so accustomed to the many uses of lead in non-dangerous phases of human environment that the name of this poison does not cause the immediate reaction of precaution and fear attached to arsenic.

Lead arsenate is the standard arsenical insecticide of most universal application for a wider range of insect control purposes than any other single type of insecticide. Paris green, in the past, was the most used as it was the first arsenical compound to gain recognition as an insecticide but its use now, though still considerable, is relatively unimportant as it has been replaced largely by lead or calcium arsenate. Calcium arsenate is affected indirectly by the residue situation which will prevent the extension of its use in some directions where it has been encroaching on Paris green. But the largest actual and potential use of calcium arsenate is for the control of the cotton insects and in this field the residue problem is not a factor.

As long ago as 1912 scientific investigation of the "possibility of danger resulting from residues of arsenate of lead remaining on fruit or foliage after spraying with that material"[2] was undertaken at the New Hampshire Agricultural Experiment Station under the direction of that able and farseeing entomologist, Dr. W. C. O'Kane.

The conclusions from this investigation covered the possible effect of spray residues on healthy human adults and also on live stock. But they were not conclusive nor were they so regarded by those who conducted them. If this investigation had been properly followed up along the lines which it indicated, there would be no spray residue problem today as it would have been solved long before.

[2] O'Kane, Hadley and Osgood, Bulletin 183, New Hamp. Agri. Exper. St.

Included in the final report was a statement by the same authority already quoted, Dr. A. J. Carlson, as follows: "Speaking as a physiologist interested in public health I should say the question is not how much of the poison may be injested without producing acute or obvious chronic symptoms, but how completely can man be safeguarded against even traces of the poison. There is no question in my mind that even in less than the so-called toxic doses lead and arsenic have deleterious effects on cell protoplasm, effects that are expressed in lowered resistance to disease, lessened efficiency, and shortening of life."

Unfortunately no agitation of the residue subject developed until several years later when it came to the front again as an issue through the condemnation of several fruit shipments from the Pacific coast by New England health officials on account of arsenical residues found thereon. These cases did not excite much public or official comment, however, nor did the occasional and unconfirmed reports of poisoning from sprayed fruit and vegetables which have appeared from time to time in the public press. In 1926 however the problem became suddenly acute on account of the condemnation of numerous shipments of American apples by English authorities. It has remained a live issue ever since. The great element of uncertainty about it, and the phase of it which absolutely prevents its prompt solution, is the fact that there is no legal tolerance or standard of limitation for the amounts of arsenic and such poisons which are permissible legally, or safe from a health standpoint, in foodstuffs.

For a considerable period every effort was made by those involved to keep this problem from discussion in the public, or trade, press on account of the fear that the public would become unduly alarmed to learn that such a problem even existed. However, in the last year so much official and unofficial mention of the subject has been made that many now question whether it can longer be considered a subject regarding which the general public can be kept in ignorance. In any event some phases of it are now getting very wide publicity in official and trade publications and the demand for a final fixing of an official or legal tolerance must ultimately force it to a solution no matter what interests are hurt by such an outcome.

One of the unaccountable phases of the present situation is the fact that many of those concerned refer to what is known as the British "tolerance" on arsenic in foodstuffs (1/100 of a grain per pound of foodstuffs) as though it were a legal requirement in England, whereas no such official tolerance has ever been adopted by the English government. Similarly, references are frequently made at public meetings and elsewhere of the official standards of "tolerance" in this country as ranging from two and one-half to four times the so-called British standard. Yet as a matter of fact there is no official or legal standard in this country either. The question is simply up in the air and apparently no one knows what the safe tolerance may be or what the legal tolerance should be.

However, as an illustration of the seriousness of the legal aspects of the problem and as showing how the shipper of foodstuffs are affected, may be cited the following from the charge of the judge in a case brought in the Federal courts involving interstate shipments of fruit. The judge said: "The statute forbids adulteration of a food product, and the articles shall be deemed to be adulterated in case of foods if they contain any added poisonous or other added deleterious ingredient which may render such article injurious to health. . . . It is not required that the article of food containing added poisonous or added deleterious ingredients must affect the public health, The word 'may' is used here in its ordinary and usual significance, there being nothing to show the intention of Congress to affix to it any other meaning." [3]

It should be stated here that although the agitation about the residue is mainly centered on apples as the most important food crop thus affected, it extends in greater or less degree through practically all other fruit crops and many of the truck crops. Until the question of tolerance is finally settled, the spray residue problem will hang over every item of foodstuffs which during the period of growth have by any possibility an opportunity to retain any stomach poison insecticide.

That there is a menace to health in the absorption of arsenic or other stomach poisons, no sane person will deny. It is therefore the part of wisdom to seek out the facts in the

[3] U. S. D. of A. notices of Judgment under the Food and Drugs Act, 15350 issued Feb. 1928.

spray residue problem rather than to deny or belittle them. To many, the word poison is synonymous with arsenic and rightly so as practically the only utility of this element, except its use in glass making, is due to its poisonous quality. Yet we may quote two apparently contradictory statements regarding arsenic in a recently published work on poisons as follows: "Arsenic is by far the most important of metallic poisons whether we consider the deadliness of its effects or the frequency of its use. . . . The peasants in parts of Styria and Hungary are said to eat arsenic, taking from two to five grains daily . . . in order that they may gain in strength and be able to endure fatigue." [4]

In connection with the present agitation about arsenical spray residues it might well be recalled that arsenic has always been feared in foodstuffs since the historical days when the king's taster had the unpleasant job of sampling the soup before it was partaken of by his majesty for fear an enemy had made his way into the royal kitchen.

More recent examples which may be cited as indicative of the fear which exists on the subject of arsenic in articles for human consumption are found in a recent article by Dr. Roe E. Remington, of the North Dakota Agricultural College, as follows: "As long ago as 1913 the North Dakota Food Commissioner set up one part per million as the maximum permitted in baking powder. . . . Arsenic in foods through chemical treatment has been familiar since the time of the Manchester beer cases through the use of impure acid in making glucose. Although the maximum amount of arsenic found in any of the samples of beer analyzed was only four parts per million, hundreds of persons were made ill and numbers died. . . . Samples of American smoking and plug tobacco have been examined for arsenic and found to contain from six to thirty parts per million, or from 9.95 to 9.27 grains of arsenic trioxide per pound. Amounts of arsenic reported are much in excess of the maximum permitted by the state and federal authorities in foods, and of the amounts normally present in plants and animals." [5]

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[4] Trumper, Memoranda of Toxicology, 1925.

[5] "A hitherto unsuspected source of arsenic in human environment," *Jour. of the Am. Ch. Soc.*, Vol. 49, No. 6, June, 1927.

It might be justly said that at the present time a great deal of earnest work is being done in connection with the residue question, new insecticides and new methods of control and reduction of the residue on fruit by washing and other methods. This work is all unintelligent however in that no one knows exactly what is required, nor can any one know this until the question of tolerance is settled.

In default of the final settling of the question of tolerance, the question will be solved with the development of a non-poisonous insecticide which will give relatively as good control for the insects considered as is now secured with the use of lead arsenate or other stomach poisons.

There is definite evidence of progress along these lines in the compounding of oil sprays and, in certain limited fields, some of the non-poisonous botanicals have evident value as contact insecticides. It is certain that any orchardist or truck grower when convinced that he can secure approximately as good control with an insecticide which eliminates the hazard of the residue problem as it now exists, will abandon the stomach poisons as a matter of common sense no matter what his dependence on them in the past. If after such a solution should come about the inertia which now prevents the question of tolerance from being settled is overcome and the result then permits the safe use of some stomach poisons within definite limitations, it will be too late then ever to restore such types of insecticides to their present status of supremacy.

On another aspect, the problem may be solved for certain types of insect control by what Dr. L. O. Howard so aptly named "the biological method of fighting insects." [6]

For several of the most important entomological problems where lead arsenate is now proscribed or threatened, the introduction of other parasitic and predatory insects is being tried out on a large systematic scale with a view of eradicating or reducing certain pests. However it takes long years of research and field work to accomplish definite results along these lines and final success is always menaced by the hazard that the new pest may be worse than the old.

As a practical workaday problem the spray residue problem

[6] "The Practical Use of the Insect Enemies of Injurious Insects," Yearbook, U. S. D. of A., 1916.

might be said to concern only the fruit and truck growers. Unfortunately the repercussions of this problem are found in many other groups, industrial, commercial, professional and official.

The entomologist is vitally interested because the greatest progress made in insect control since economic entomology attained the status of a science, has been largely based on the use of arsenical compounds. And the other stomach poisons are, of course, threatened by the same ban which hangs over arsenic. But the entomologist, not being a medical man, does not know which one to pick.

The entomologists are therefore striving to solve a problem of selecting materials for insect control work when they are completely in the dark as to what materials they will be permitted to use in the future.

The insecticide manufacturers are also vitally interested in this problem, both those making arsenical compounds or other stomach poison insecticides and those making only contact or repellant insecticides. The fog of uncertainty which hangs over these industries on account of the unknown factor of spray tolerance has caused stagnation of effort in extending existing industries or developing new ones.

The shippers of fruit and other foodstuffs affected are sorely harassed and disturbed on account of the ever present danger of official seizure of the commodities in which they deal and the still greater danger that the public may take alarm at a possible danger, and, through hysteria excited by the sound of the word arsenic, may suddenly turn against types of foodstuffs produced in various agricultural districts.

The group which must necessarily take cognizance of this problem, and whose final recognition of it brought about the present crisis, includes the pure food law and health law officials, federal, state and municipal. They are faced with a possible ambiguity of the laws on the one hand and lack of medical knowledge on the other. Also they fear that they may so handicap the entomologist that it will be impossible to protect the very crops which they desire to be kept free from poisonous contamination.

Obviously the spray residue problem is a complex one, affecting as it does so many important groups. In its finality

however it must be met by medical science along the lines so ably summed up by Dr. Carlson. Those of us who are mainly interested in arsenic and other stomach poisons must take into account the fact that it is primarily a problem which must be settled first in terms of toxicology and physiology and all other phases of it worked out from a basis of standards set by those sciences. Until it is so settled all the groups affected will remain in a state of uncertainty and chaos. And the danger will continue of a public hysteria which may result in a calamity to some of the agricultural groups involved.

SCHRÖDINGER DYNAMICS.

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The Schrödinger theory is based on the hypothesis that the fundamental properties of the electron can be derived from the solutions of the wave equation

$$\nabla^2\psi - \frac{1}{u^2}\frac{\partial^2\psi}{\partial t^2} = 0 \tag{1}$$

with

$$u^2 = \frac{E^2}{2m(E - V)},$$

where V is the potential energy function, the same as was used in the classical quantum theory to describe the energy of the external forces acting on the electron, where m is the mass of the electron and where E is a characteristic constant whose value represents the total amount of energy the atomic system has available for radiation.

When, however, we attempt to analyze the properties of the electron still further so as to find, e.g., the distribution of charge density or the motion of the center of electronic mass—so far we have only found a method to determine the value of the energy available as radiation, i.e., the value of E—we encounter grave difficulties. Various hypotheses have been made, none of which seems to be completely satisfactory.

The most direct method, however, is to assume that the motion of the electron is such that the direction of its motion coincides with the direction of the normal to the wave surfaces ψ = constant. This is one of the important results which the experiment of Davisson and Germer has demonstrated and which, therefore, rests on a sound experimental basis. We are also familiar with a similar hypothesis in the quantum

theory of radiation in which the light quantum is supposed to travel along the normal to the wave front, in the case of a plane wave, found as a solution of the equation

$$\nabla^2\psi - \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2} = 0. \tag{2}$$

These two wave equations (1) and (2) which specify the motion of the electron and quantum, respectively, have several properties in common. The frequency of the vibrations of the function ψ appearing in equation (2) is given by by the relation

$$\nu = E/h,$$

where E is the amount of radiant energy associated with one quantum and " h " is Planck's constant; in the wave theory of the electron's motion a similar relationship holds. The frequency of the vibrations of ψ in this case is given by the relation,

$$\nu = E/h;$$

here E represents the amount of energy available as radiant energy.

We can, therefore, treat these two distinct equations as special cases of the general wave equation

$$\nabla^2\psi - \frac{1}{u^2}\frac{\partial^2\psi}{\partial t^2} = 0,$$

$$\psi(x\ y\ z\ t) = \bar{\psi}(x\ y\ z)e^{(2\pi i/h)Et},$$

where E has the significance mentioned above, and where $u^2 = c^2$ for the quantum phenomena of optics, and

$$u^2 = \frac{E^2}{2m(E - v)}$$

for electronic phenomena.

Substituting the value of ψ in terms of $\bar{\psi}$ and the time t, we find the spatial equation

$$\nabla^2\bar{\psi} + \frac{4\pi^2E^2}{u^2}\bar{\psi} = 0 \tag{3}$$

as the general equation from which the properties of the motion of the particle may be investigated.

We shall now proceed to derive the equations of motion of the electron or quantum on the basis of the assumption we have discussed above, namely, that the direction cosines l, m and n of the normal to the surface

$$\bar{\psi}(xyz) = \text{constant},$$

where

$$l = \frac{\partial\bar{\psi}}{\partial x}\Big/\sqrt{\left(\frac{\partial\bar{\psi}}{\partial x}\right)^2 + \left(\frac{\partial\bar{\psi}}{\partial y}\right)^2\left(\frac{\partial\bar{\psi}}{\partial z}\right)^2}$$

and where similar expressions hold for m and n, that these direction cosines are equal to the direction cosines α, β and γ of the tangent to the particles trajectory at the same point where

$$\alpha = \frac{dx}{dt}\Big/\sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 + \left(\frac{dz}{dt}\right)^2}$$

and similar expressions for β and γ.

We shall now limit the discussion to the case where the momenta

$$px = m\frac{dx}{dt}, \quad \text{etc.}$$

can be expressed as a function of position independent of the time, i.e., we shall set

$$px = \frac{\partial W}{\partial x}, \quad \text{etc.}$$

Since it is only problems of mechanics where a yelocity potential exists which can be solved completely, this restriction merely limits our attention to those problems which are of interest.

Equating now the components of the direction cosines, we have that

$$\frac{\partial\bar{\psi}}{\partial x}\Big/\sqrt{\left(\frac{\partial\bar{\psi}}{\partial x}\right)^2 + \left(\frac{\partial\bar{\psi}}{\partial y}\right)^2 + \left(\frac{\partial\bar{\psi}}{\partial z}\right)^2}$$
$$= \frac{\partial W}{\partial x}\Big/\sqrt{\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2}$$

together with two other equations for the "y" and "z" components whose solution is that $\bar{\psi}$ is a function of W,

$$\bar{\psi} = f(W).$$

If now we substitute this value for $\bar{\psi}$ in terms of W into the spatial equation

$$\Delta^2\bar{\psi} + \frac{4\pi^2E^2}{u^2}\bar{\psi} = 0$$

we shall have a differential equation for W, from which to determine the motion of the particle.

Making the substitution for $\bar{\psi}$ in terms of W, we have since

$$\frac{\partial\bar{\psi}}{\partial x} = f'\frac{\partial W}{\partial x}, \qquad f' = \frac{\partial f}{\partial W}$$

and

$$\frac{\partial^2\bar{\psi}}{\partial x^2} = f''\left(\frac{\partial W}{\partial x}\right)^2 + f'\frac{\partial^2 W}{\partial x^2},$$

that

$$f'[\nabla^2 W] + f''\left[\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2\right] + \frac{4n^2E^2}{u^2}f = 0$$

or, dividing by f and replacing u^2 by its value for the electron, namely

$$u^2 = E^2/2m(E - V)$$

we have that

$$\left(\frac{f'}{f}\right)[\nabla^2 W] + \left(\frac{f''}{f}\right)\left[\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2\right] + \frac{8\pi^2 m}{h^2}(E - V) = 0. \quad (4)$$

In order to find the form of the function $f(W)$ we will have to use the principle that the quantum phenomena degenerate into the phenomena of classical mechanics as Planck's constant "h" approaches zero. For example, we have from Planck's radiation theory that the energy density of radiation belonging to wave lengths between λ and

$\lambda + d\lambda$, $L(\lambda)d\lambda$, is given as a function of the temperature T and the wave-length λ by

$$L(\lambda)d\lambda = \frac{8\pi^2 ch}{\lambda^5}\frac{d\lambda}{e^{ch/RT} - 1},$$

where

$$c = \text{velocity of light}$$

and

$$R = \text{gas constant.}$$

If now we take the limit of $L(\lambda)d\lambda$ as h approaches zero, we obtain as the value of $L(\lambda)d\lambda$ $L(\lambda)d\lambda = \dfrac{8\pi RT}{\lambda^4}d\lambda$, the Rayleigh-Jeans' law which is based on classical mechanics.

The restriction is similar to the one of restricted relativity in that if we allow the value of the constant "c," the velocity of light, which appears in the equations of relativity, to approach infinity, the equations of motion degenerate into the laws of classical mechanics.

We shall now use the above principle to determine the form of the function $f(W)$ so that this condition is satisfied.

Since in the limit when $h = 0$, equation (4) has the form

$$\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2 - 2m(E - V) = 0,$$

then

$$\operatorname*{limit}_{h \doteq 0} f'/f = 0$$

and

$$\operatorname*{limit}_{h \doteq 0} f''/f = -\frac{4\pi^2}{h^2}.$$

A solution of these two equations is

$$f(W) = e^{(2\pi i/h)W},$$

so that the energy equation (4) takes the form

$$\frac{h}{2\pi i}\nabla^2 W + \left[\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2 - 2m(E - V)\right] = 0. \quad (5)$$

The above equation represents the energy integral of the equations of motion of an electron which is consistent with the two restrictions (i) that the direction of the normal to the wave surfaces $\overline{\psi}$ = constant is the same as the direction of the tangent to the trajectory of the electron's motions passing through the same point in space and (ii) that the energy integral degenerates as $h = 0$ to the energy integral of classical mechanics.

If we had started from the spatial equation for the light quantum instead of that for the electron we would have, by the same process of analysis, arrived finally at the energy integral

$$\frac{h}{2\pi c}\nabla^2 W + \left[\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2 - \left(\frac{E}{c}\right)^2\right] = 0. \quad (6)$$

The solution of this equation is subject to no other conditions than those required by the periodicity of the motion.

Since the energy integral, equation (5), corresponds to the motion of an electron which does not radiate any energy beyond the confines of the system, i.e., into space where an observer can detect the same, the motion must be such that the value of the momenta $px = \frac{\partial W}{\partial x}$, etc., must assume for any point on the trajectory the same values after every complete revolution or cycle of the system. For example, in the case of the rotator, which consists of a particle of mass M moving in a fixed circle about a center of constraint, the origin, the value of the momentum $p\theta$, if we use polar coördinates in which the angle θ is used to designate the position of the particle, must assume the same value after every increase or decrease of the angle θ by 2π. This is equivalent to assuming that the momenta, in the case where the motion is cyclic, are independent of the time, explicitly, and can therefore be expressed as the derivates of a velocity potential, or, in other words, as a point function.

We shall now consider the type of motion of the electron and light quantum respectively in a few simple cases which are of particular interest.

THE FREE ELECTRON.

The wave equation for the free electron is

$$\nabla^2\psi - \frac{2m}{E}\frac{\partial^2\psi}{\partial t^2} = 0,$$

so that the energy equation of the electron itself has the form

$$\frac{h}{2\pi i}\nabla^2 W + \left[\left(\frac{\partial W}{\partial x}\right)^2 + \left(\frac{\partial W}{\partial y}\right)^2 + \left(\frac{\partial W}{\partial z}\right)^2 - 2mE\right] = 0.$$

or if the motion is restricted to paths which are parallel to the x-axis in the Cartesian coördinate system we are employing,

$$\frac{h}{2\pi i}\frac{\partial^2 W}{\partial x^2} + \left(\frac{\partial W}{\partial x}\right)^2 = 2mE.$$

If we set $\dfrac{\partial W}{\partial x} = p =$ momentum of electron along x-axis, then the equation takes the form

$$\frac{h}{2\pi i}\frac{\partial p}{\partial x} + p^2 - 2mE = 0,$$

whose general integral is

$$\frac{1}{\sqrt{2mE}}\log\frac{p - \sqrt{2mE}}{p + \sqrt{2mE}} = \frac{2\pi i}{h}x + c,$$

where c = constant; or

$$\frac{p - \sqrt{2mE}}{p + \sqrt{2mE}} = A\cos\frac{2\pi}{h}\sqrt{2mE}\cdot x;$$

or

$$p = \sqrt{2mE}\left\{\frac{1 \pm A\cos\frac{2\pi}{h}\sqrt{2mE}\cdot x}{1 \mp A\cos\frac{2\pi}{h}\sqrt{2mE}\cdot x}\right\}. \qquad (7)$$

The velocity of the electron p/m in the case is no longer constant, but fluctuates about a mean value, which is the

same as the classical value, namely, $\frac{\bar{p}}{m} = \sqrt{2mE}/m$, mean value of velocity.

The fluctuations are such that when the electron traverses a distance

$$\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\bar{p}}$$

the value of the momentum is the same at the two end points. Moreover, we see that this distance λ is the same as the wave-length of the de Broglie waves associated with the particle so that we can regard these fluctuations in velocity as due to the reaction of the ψ field on the electron, retarding or accelerating it as the phase angle between the vector field and the direction of motion changes.

If we regard the constant E, as the energy available as radiation, rather than as the total energy of the system, then from the above equation we see that the energy E is the same as the kinetic energy of the particle calculated by the classical mechanics, i.e.,

$$E = \left| \frac{\bar{p}^2}{2m} \right| \quad \text{mean value,}$$

a result which has its experimental verification in the wave-length limit of the continuous X-ray spectrum.

From equation (7) which expresses the relationship existing between the momentum and the coördinate x, we see that we cannot assign any definite value to the momentum and, therefore, to the kinetic energy of the particle, but only a mean value about which these quantities oscillate as the particle describes the trajectory, the value of the oscillation depending on the value of the constant of integration A. The fact that we cannot assign a definite value to the energy of a free electron but only a mean value is in keeping with the spirit of the principle of indetermination which lately has been developed by Heisenberg and others.

The wave mechanics definition of charge density as the product of ψ by its conjugate imaginary leads to the conception of the wave packet which behaved like a point mass

of the usual mechanics. The discovery that this wave packet diffused itself indefinitely with the time caused a revision of this conception and lead to the principle of indetermination formulated by Heisenberg. In this paper we replace the conception of the indetermination of the path of a particle by the indetermination in the particular path the particle may move along. In the quantum theory of diffraction the light particles move along the lines of the Poynting flux but which particular line they choose to traverse is determined wholly, as yet, by probability considerations: in this theory of the free electron the same situation arises and brings the indetermination into the choice of the path rather than on the path itself.

However, as we shall see later, the path of the election itself is uniquely determined for those cases where the energy E is assigned to certain fixed values.

In these cases, however, the momentum and kinetic energy of the free electron may vary within definite limits, given by the constant A, about a mean value, although the value of the energy available as radiation, i.e., E, is definite and is equal to the mean value of the kinetic energy. The difference in energy between these two values, which arises when the particle liberates the energy E due to a collision or a radiation process, is taken up by the adjustment of the electron's field ψ and in its internal rearrangement due to the dependence of its mass density on velocity.

THE LIGHT QUANTUM.

We have for the energy integral of a quantum moving parallel to the direction of the x axis,

$$\frac{h}{2\pi i}\frac{\partial^2 W}{\partial x^2} + \left(\frac{\partial W}{\partial x}\right)^2 - \left(\frac{E}{c}\right)^2 = 0$$

or setting $\dfrac{\partial W}{\partial x} = p =$ momentum in the x direction

$$\frac{h}{2\pi i}\frac{\partial p}{\partial x} + p^2 - \left(\frac{E}{c}\right)^2 = 0,$$

whose solution is

$$\frac{p - E/c}{p + E/c} = A \cos \frac{2\pi}{p}\left(\frac{E}{c}\right) \cdot x.$$

We have, therefore, that the average value of the momentum p is equal to the radiant energy E associated with one quantum divided by the velocity of light, $\bar{p} = E/c$, a mean value.

The distance λ which the quantum must travel from any given point before the momentum p repeats its previous value is given by the equation

$$\lambda = hc/E,$$

the same as the wave-length of the light pulse, since

$$\frac{\lambda}{c} = \frac{1}{\nu} = h/E.$$

For electromagnetic radiation the value of the constant A must be extremely small, otherwise the modified line in the Compton Effect would have a large width, measured in wave-length units, compared to that of the unmodified line.

THE ROTATOR.

Using polar coördinates, we have for the energy integral of the rotator since here the potential energy V is zero

$$\frac{h}{2\pi i}\left[\frac{\partial^2 W}{\partial r^2} + \frac{2}{r}\frac{\partial W}{\partial r} + \frac{1}{r^2}\frac{\partial^2 W}{\partial \theta^2} + \frac{1}{r^2}\cot\theta\frac{\partial W}{\partial \theta} + \frac{1}{n^2 \sin^2\theta}\frac{\partial^2 W}{\partial \varphi^2}\right]$$
$$+ \left[\left(\frac{\partial W}{\partial r}\right)^2 + \frac{1}{r^2}\left(\frac{\partial W}{\partial \theta}\right)^2 + \frac{1}{r^2 \sin^2\theta}\left(\frac{\partial W}{\partial \varphi}\right)^2 - 2mE\right] = 0.$$

Since, however, in the rotator, the particle of mass m is constrained to lie on a sphere of constant radius r measured from the origin, we have for the energy equation, limiting the discussion to the case where the particle moves only in the plane φ = constant,

$$\frac{h}{2\pi i}\left(\frac{\partial^2 W}{\partial \theta^2}\right)^2 + \left(\frac{\partial W}{\partial \theta}\right)^2 - 2mr^2E = 0,$$

whose solution is

$$\frac{\dfrac{\partial W}{\partial \theta} - \sqrt{2mE}\cdot r}{\dfrac{\partial W}{\partial \theta} + \sqrt{2mE}\cdot r} = A \cos\left(\frac{2\pi}{h}\sqrt{2mE}\cdot r\theta\right)$$

or setting

$$\frac{1}{r}\frac{\partial W}{\partial \theta} = p = \text{momentum of the particle}$$

$$\frac{p - \sqrt{2mE}}{p + \sqrt{2mE}} = A \cos\left(\frac{2\pi}{h}\sqrt{2mE}\cdot r\theta\right).$$

Here again the average value of the momentum is given by

$$\bar{p} = \sqrt{2mE}, \quad \text{a mean value,}$$

and the wave length λ of the oscillation by

$$\lambda = h/\sqrt{2mE} = h/\bar{p},$$

the same type of expression as for the free electron. In this case, however, we can determine the value of the constant E from the condition that the motion must be periodic since there is no radiation of energy outside the system which an observer might detect. We have, therefore, that when the angle θ increases by an amount equal to 2π, the momentum has the same value as initially. Thus

$$\frac{4\pi^2}{h}\sqrt{2mE}\cdot r = 2\pi n, \quad n = \text{integer}$$

or

$$E = \frac{n^2h^2}{8\pi^2mr^2}.$$

The periodicity condition leads to the same value for the energy available as radiation as that given by the wave equation, an amount of energy equal to the average value of the kinetic energy of the particle.

HYDROGEN ATOM.

The solution of the hydrogen atom is of particular importance because it leads to interesting results concerning

the orbit of the electron and the wave-length of the ψ waves associated with its motion.

The hydrogen atom is the first case which we have treated where the potential energy V plays a role,

$$V = -\frac{e^2}{r}.$$

We shall attempt to find a solution of the energy equation expressed in polar coördinates by assuming that the function W can be expressed as the sum of these separate functions, each a function of one variable only

$$W = R(r) + \Theta(\theta) + \Phi(\varphi),$$

then the energy integral takes the form

$$\frac{h}{2\pi i}\left[\frac{\partial^2 R}{\partial r^2} + \frac{2}{r^2}\frac{\partial R}{\partial r} + \frac{1}{r^2}\frac{\partial^2\Theta}{\partial\theta^2} + \frac{1}{r^2\sin\theta}\frac{\partial^2\Phi}{\partial\varphi^2} + \frac{\cot\theta}{r^2}\frac{\partial\Theta}{\partial\theta}\right]$$
$$+\left[\left(\frac{\partial R}{\partial r}\right)^2 + \frac{1}{r^2}\left(\frac{\partial\Theta}{\partial\theta}\right)^2 + \frac{1}{r^2\sin^2\theta}\left(\frac{\partial\Phi}{\partial\varphi}\right)^2 - 2m(E - V)\right] = 0,$$

an equation which we can write in the form

$$\frac{hr^2}{2\pi i}\left[\frac{\partial^2 R}{\partial r^2} + \frac{2}{r}\frac{\partial R}{\partial r}\right] + r^2\left(\frac{\partial R}{\partial r}\right)^2 - 2mr^2\left(E + \frac{e^2}{r^2}\right)$$
$$= -\frac{h}{2\pi i}\left[\frac{\partial^2\Theta}{\partial\theta^2} + \cot\theta\frac{\partial\Theta}{\partial\theta}\right] - \left(\frac{\partial\Theta}{\partial\theta}\right)^2$$
$$-\frac{1}{\sin^2\theta}\left[\frac{h}{2\pi i}\frac{\partial^2\Phi}{\partial\varphi^2} + \left(\frac{\partial\Phi}{\partial\varphi}\right)^2\right].$$

Since each side of this equation is a function of a different variable, we can equate each to a constant β, then we have that

$$\frac{h}{2\pi i}\left[\frac{\partial^2\Theta}{\partial\theta^2} + \cot\theta\frac{\partial\Theta}{\partial\theta}\right] + \left(\frac{\partial\Theta}{\partial\theta}\right)^2 = \beta - \frac{1}{\sin\theta}\left[\frac{h}{2\pi i}\frac{\partial^2\Phi}{\partial\varphi^2} + \left(\frac{\partial\Phi}{\partial\bar{\varphi}}\right)^2\right],$$

an equation which we can write in the form of two separate equations,

$$\frac{h}{2\pi i}\frac{\partial^2\Phi}{\partial\varphi^2} + \left(\frac{\partial\Phi}{\partial\varphi}\right)^2 = \gamma \tag{8}$$

and

$$\frac{h}{2\pi i}\left[\frac{\partial^2\Theta}{\partial\theta^2} + \cot\theta\frac{\partial\Theta}{\partial\theta}\right] + \left(\frac{\partial\Theta}{\partial\theta}\right)^2 = \beta - \frac{\gamma}{\sin^2\theta}, \tag{9}$$

where γ is an undetermined constant.

The solution of (8) is

$$\frac{\dfrac{\partial\Phi}{\partial\varphi} - \sqrt{\gamma}}{\dfrac{\partial\Phi}{\partial\varphi} + \sqrt{\gamma}} = Ae^{(2\pi i/h)\sqrt{\gamma}\varphi}.$$

From the periodicity condition, the momentum $\partial\Phi/\partial\varphi$ must repeat its values when φ increases by 2π, and we have that

$$\frac{2\pi}{h}\sqrt{\gamma} = n, \quad \text{where } n = \text{an integer.} \tag{10}$$

We shall omit the discussion of this equation for the present and wait until we have solved the problem completely when we shall be in a better position to understand its significance.

The solution of the equation

$$\frac{h}{2\pi i}\left[\frac{\partial^2\Theta}{\partial\theta^2} + \cot\theta\frac{\partial\Theta}{\partial\theta}\right] + \left(\frac{\partial\Theta}{\partial\theta}\right)^2 + \frac{\gamma}{\sin^2\theta} = \beta$$

can be simplified if we set

$$\sin\theta\frac{\partial\Theta}{\partial\theta} = \frac{\partial\mu}{\partial\theta};$$

then we have that μ satisfies the equation

$$\frac{h}{2\pi i}\left[\sin\theta\frac{\partial^2\mu}{\partial\theta^2}\right] + \mu^2 + \gamma - \beta\sin^2\theta = 0.$$

A particular solution of this equation which corresponds to the motion of the electron in a circular orbit is

$$\mu = a\cos\theta$$

where a and β satisfy the equations

$$a^2 = -\gamma$$

and

$$\beta = -\left(a^2 + \frac{ah}{2\pi i}\right) = \left(\gamma \pm \sqrt{\gamma}\frac{h}{2\pi}\right).$$

Thus we have that

$$\frac{\partial \Theta}{\partial \theta} = i\sqrt{\gamma}\cot\theta = -\frac{nh}{2\pi i}\cot\theta$$

and

$$\beta = \frac{h^2}{4\pi^2}(n^2 \pm n).$$

Since the momentum $\frac{1}{r}\frac{\partial \Theta}{\partial \theta}$ cannot be imaginary, the trajectory of the electron must lie in the plane

$$\theta = \pi/2.$$

The solution of the equation, Riccati's equation,

$$\frac{h}{2\pi i}\frac{\partial P}{\partial r} + \frac{h}{\pi i}\frac{P}{r} + P^2 = \frac{-\beta}{r^2} + 2m\left(E + \frac{e^2}{r}\right), \qquad P = \frac{\partial R}{\partial r}$$

can be simplified if we set

$$P = \frac{h}{2\pi i}\frac{u'}{u}, \qquad u' = \frac{\partial u}{\partial r},$$

for then the equation takes the familiar form

$$\frac{d^2u}{dr^2} + \frac{2}{r}\frac{du}{dr} - \left\{\frac{\beta''}{r^2} - K\left(E + \frac{e^2}{r}\right)\right\} = 0,$$

where

$$K = \frac{8\pi^2 m}{h^2} \quad \text{and} \quad \beta'' = -\frac{4\pi^2\beta}{h^2}.$$

If we set

$$u = e^{\lambda r}\cdot y,$$

then we obtain the equation

$$\frac{d^2y}{dr^2} + \left(2\lambda + \frac{2}{r}\right)\frac{dy}{dr} + \left(KE + \lambda^2 + \frac{2\lambda - Ke^2}{r} - \frac{\beta''}{r^2}\right)y = 0,$$

from which we can eliminate the constant term in the factor multiplying y by setting

$$\lambda^2 + KE = 0,$$

$$\lambda = \pm \frac{2\pi i}{h}\sqrt{2mE}.$$

In order to eliminate the term in $1/r$ from the coefficient of y, we set

$$y = r^\sigma \cdot v,$$

obtaining an equation in v of the form

$$\frac{d^2v}{dr^2} + \left[2\lambda + \frac{2(\sigma + 1)}{r}\right]\frac{dv}{dr} - \left[\frac{Ke^2 - 2\lambda - 2\sigma\lambda}{r} - \frac{\beta'' + \sigma(\sigma + 1)}{r^2}\right]v = 0.$$

Choosing σ so that

$$\sigma = \frac{Ke^2}{2\lambda} - 1,$$

we finally obtain the equation

$$\frac{d^2v}{dr^2} + \left[2\lambda + \frac{2(\sigma + 1)}{r}\right]\frac{dv}{dr} + \left[\frac{\beta'' + \sigma(\sigma + 1)}{r^2}\right]v = 0.$$

whose solution can be represented by a series in l/r, a series, however, since it must be finite for all values of r, excluding the origin, must either terminate or be convergent in this interval. This condition is equivalent to assuming that the momentum in the radial direction $\partial R/\partial r$ must always be finite.

A solution of the equation, which corresponds to the case of circular orbits, is v = constant, so that $\beta'' = -\sigma(\sigma + 1)$; but

$$\beta'' = -n(n \pm 1)$$

so that

$$\begin{aligned} \sigma &= n \text{ or } -(n + 1) \quad \text{using the } + \text{ sign,} \\ &= -n \text{ or } (n - 1) \quad \text{using the } - \text{ sign.} \end{aligned}$$

Since

$$\lambda = \frac{\pm 2\pi i}{h}\sqrt{2mE}$$

and

$$\sigma = \frac{Ke^2}{2\lambda} - 1 = \frac{2\pi me^2}{p\sqrt{-2mE}} - 1,$$

we see that the condition σ = an integer cannot be satisfied unless E is negative. Setting $-E = \epsilon$ we find for the type of periodic motion we have been investigating that only certain values for the energy available as radiation are allowable, namely those for which the relation

$$\epsilon = \frac{2\pi^2 me^4}{h^2(n)^2}, \quad \text{where } n = \text{integer}, \tag{11}$$

is satisfied, a condition which is the same as that demanded by the wave theory.

The value of the momentum $\partial R/\partial r$ of the electron along the radius vector, is given by

$$\frac{\partial R}{\partial r} = \frac{h}{2\pi i}\frac{\partial}{\partial r}\log\,(e^{\lambda r}\cdot r^{\sigma}) = \frac{h}{2\pi i}\left[\lambda + \frac{\sigma}{r}\right],$$

but since the momentum cannot be imaginary, the momentum must be zero, and the electron describes a circular orbit whose radius r is given by

$$r = -\frac{\sigma}{\lambda}$$

$$= \frac{n(n+1)h^2}{4\pi^2 me^2}. \tag{12}$$

It is interesting to compare the value of the radius of the circular orbits of the wave theory, given by the above expression, with those of the Bohr theory for which the radius of the orbit is given by

$$r = \frac{n^2h^2}{4\pi^2 me^2}$$

for the same value of the energy E.

The momentum $p = \frac{1}{r}\frac{\partial\Phi}{\partial\varphi}$ of the electron in its orbit fluctuates about the mean value

$$\bar{p} = \left|\frac{1}{r}\frac{\partial\Phi}{\partial\varphi}\right| = \frac{nh}{2\pi r} = \frac{2\pi me^2}{(n+1)h} \text{ mean value}$$

and the angular momentum varies about the mean value $nh/2\pi$, the same as in the Bohr theory.

The distance which the electron moves before the momentum repeats its value, i.e., the wave-length of the oscillation is given by

$$\lambda = \frac{\sqrt{\gamma}}{hr} = \frac{2\pi me^2}{(n+1)h^2} = \frac{\bar{p}}{h}$$

or the wave-length of the oscillation is equal to the average momentum in the orbit divided by Planck's constant, a value analogous to that of the free electron.

A Glimpse at the Electrical Changes that Take Place in a Billionth of a Second. W. ROGOWSKI. (*Naturwissenschaften*, March 9, 1928.) For years the author has been investigating the course of rapid electrical processes for the purpose of making them visible and inscribing them on the photographic plate. One such process would be the flow of current into a line upon the closing of a switch. On account of its inertia the moving part of a galvanometer cannot instantly follow the growth of current in the line. A Braun tube, however, has the great advantage of possessing as its pointer a practically massless beam of electrons. In a tube evacuated to a pressure of .001 mm. a potential difference of 30,000 volts between the electrodes causes electrons to travel from the cathode toward the anode which is pierced with a hole. Many impinge on the anode but some pass through the hole and fall on a fluorescent screen some distance away, where they make a bright spot. If the electron beam be subjected to a permanent electrical force the spot will be deflected and if the force vary the spot will change its position accordingly. If two forces at right angles to each other and to the path of the beam act on the electrons the position of the spot will be due to both forces and if both vary in intensity the spot will describe some path. Moreover if one force vary in a known manner the method of variation of the other can be deduced from the form of the path of the light spot. At first the curve of the spot was photographed from the outside of the tube. Thus Zenneck succeeded in tracing processes one-thousandth of a sec. in duration. The photographic plate was next put inside the tube so that the electrons fell directly upon it. With this improvement changes are registered that take place in .00001 to .000001 sec. A further advance was made by directing the electrons so that all passed through the hole in the anode instead of many wasting themselves on the metal of the electrode. This made it possible to get a photographic record of what occurs in a billionth of a second. The substitution of a hot cathode has the advantage of assuring a plentiful supply of electrons but this is at the expense of a great deal of scattering. Curves obtained for almost instantaneous changes such as the discharge of a capacity through a circuit have abscissas in which 4 or 5 mm. equals .0000001 sec. G. F. S.

A NEW FIRST ORDER THEODOLITE.

BY

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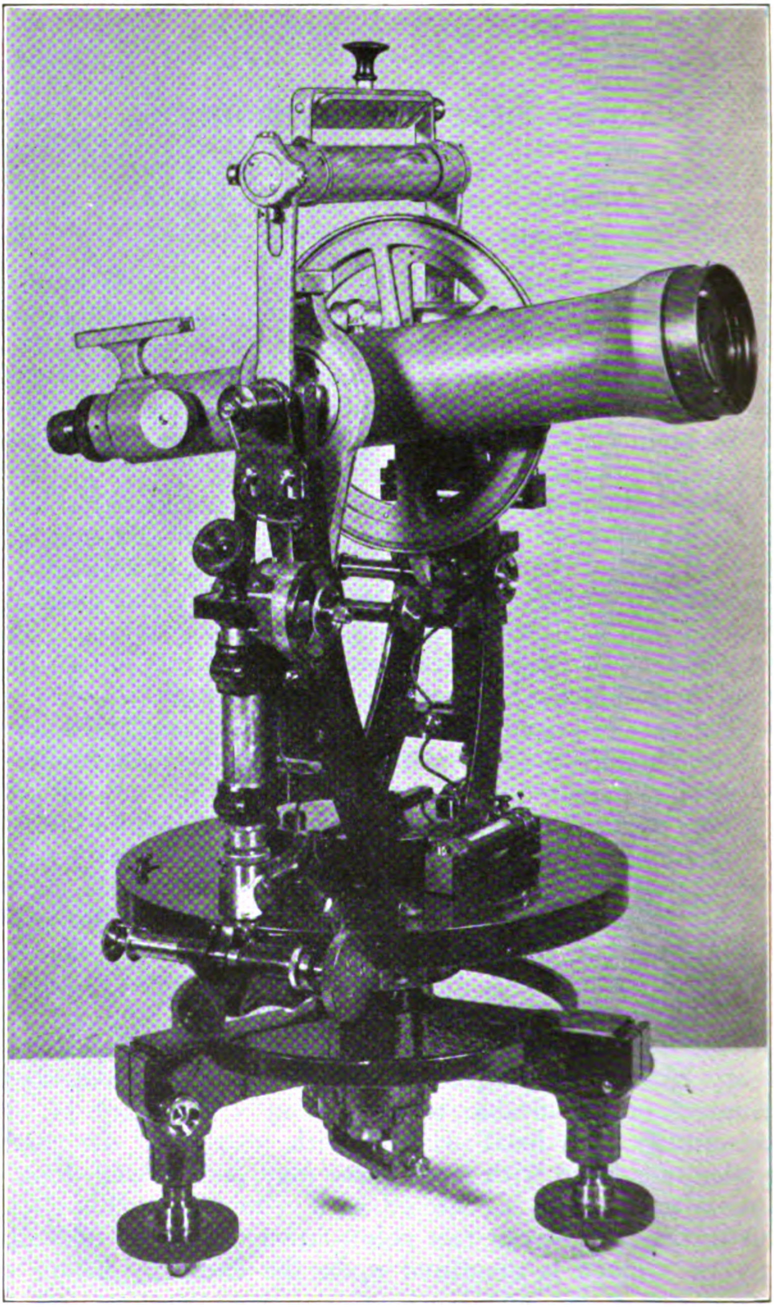
A RAPID increase in land values, the increase in number and magnitude of public and private engineering works and the greater demand for maps of all parts of the country and the coast by a mobile population, has created a necessity for the completion at an early date of the precise control surveys of the country, on which are based the coastal charts and topographic maps of the interior.

These precise surveys, technically designated as Geodetic by virtue of their taking into consideration the irregular curved figure of the earth, are performed with instruments of special accuracy, designed for the purpose, by which measurements in the field are made with laboratory accuracy. The development of these instruments presents some interesting scientific and mechanical engineering problems.

The two principal instruments used are the precise level and the theodolite, the first being used in the determination of exact differences in elevation and the second for the accurate measurement of the angles of the triangles laid off in trigonometric surveys. The theodolite is by far the more complicated of the two and as its design and construction embody practically all the problems involved in the level as well as those peculiar to itself, this instrument only, as developed by the U. S. Coast and Geodetic Survey, will be described in this article.

The theodolite is purely an angle measuring device. In theory it is quite simple, consisting of a graduated circle mounted on a suitable leveling head which may be set horizontally in a fixed azimuth with respect to the earth. A telescope fitted with cross wires may be revolved upon a vertical axis which is centered with reference to this circle, and the angle between two points upon which the telescope may be trained is measured upon the circle by means of

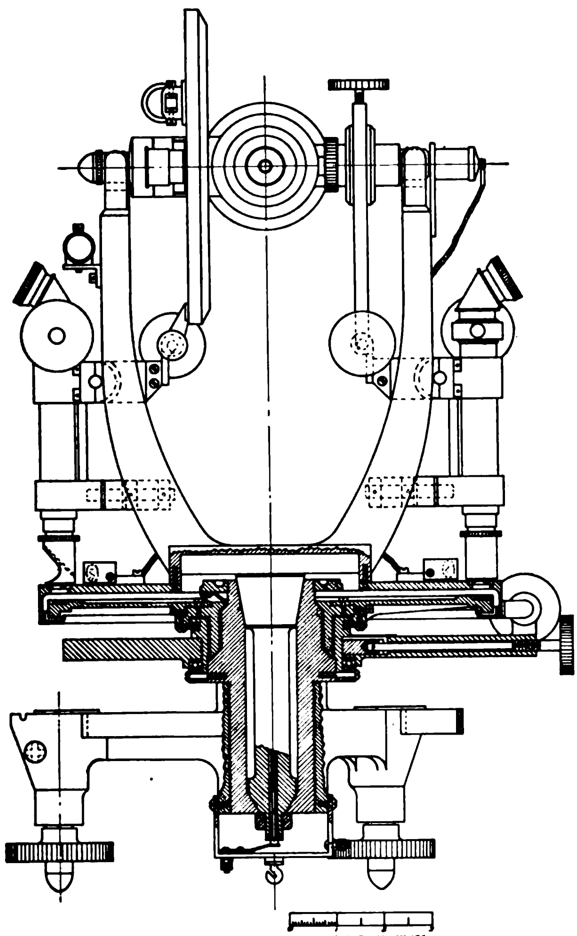
FIG. 1.



suitable micrometer microscopes attached to the telescope standard.

To design and construct an instrument which will accomplish this angular measurement with the necessary refinement

Fig. 2.



is considerably more of a problem than would appear from the above description. The mechanical fit of various parts must be of the closest and there are certain elements of design which vitally affect the quality of the finished instru-

ment. For instance, there must be no appreciable change in the fit of the vertical axis bearing due to changes in temperature and there must be no frictional drag between the telescope element, or alidade, and the graduated circle. The entire design must be made with a view to ruggedness and speed of manipulation and to provide for simple and easy adjustment under field conditions. In the new instrument developed by the U. S. Coast and Geodetic Survey (see Figs. 1 and 2), these various elements have been fully provided for and field tests have proven it to be one of the most accurate, rapid and durable instruments which the Bureau has ever used.

The theodolite has a 9-inch circle graduated to five minutes and reads directly to one second by each of two micrometer microscopes located 180° apart. The circle is of the floating type, which means that its bearing is entirely separated from that of the alidade and that it has no clamp. It is read by vertical micrometer microscopes fitted with angle eyepieces to facilitate observation.

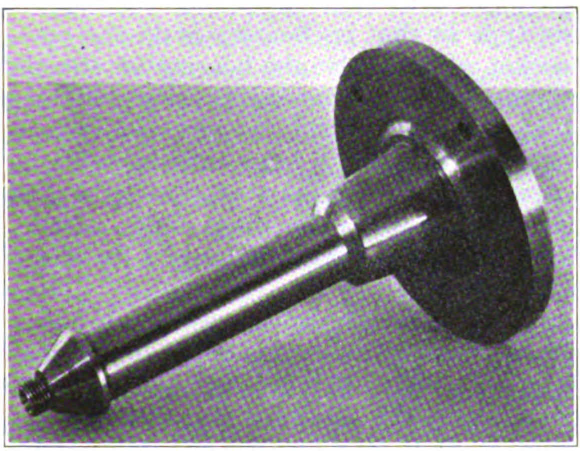
The telescope is of the internal focusing type, which assists in making it dust and moisture proof, and has a large objective to admit a maximum of light, a valuable consideration in night surveying. A ten-second, six-inch circle is mounted in the usual manner for vertical angle measurements.

The leveling head is of a stiff aluminum alloy, and is of the three armed design. The leveling screws have a medium pitched thread and are unusually large, being one-half inch in diameter, with threads carefully fitted into the head casting, an important consideration as any play at this point may cause an apparent shifting of the circle in azimuth. The leveling screws are provided with clamps. A fine grained iron casting is threaded and shrunk into the center of the leveling head as a bearing for the alidade and graduated circle plate. The design of the bearing surfaces of both vertical axis and circle is of especial importance as it is here that changes in fit due to changes in temperature may cause serious error. If the bearings become too tight, too great an effort is necessary to turn the alidade and may cause a shifting of the instrument in azimuth with resultant error in reading. On the other hand, too loose a fit will cause a wobbling of the

alidade, which is certain to result in errors. In the customary single-cone type of vertical axis for such instruments, a vertical thrust adjustment is usually furnished and some instruments require frequent adjustment of this device.

These changes in fit are automatically compensated for in the new theodolite by an inherent characteristic of the design in that the vertical axis bearing is made up of two conical surfaces, an acute cone at the top to take care of sideways fit and an obtuse cone at the bottom to take up thrust. (See Fig. 3.) These two cones are designed to meet at a

FIG. 3.



common apex and in consequence the bearing elements of axis and socket are parts of similar triangles and regardless of differences of temperature coefficient, expansion or contraction both laterally and longitudinally are always in proportion and the fit is maintained. The same type of bearing is used for the horizontal circle, although its use for this element is not so important.

The vertical axis is a forging of unhardened, high grade, tool steel, the part being left unhardened in order to avoid the setting up of internal stresses in hardening which might eventually release themselves and cause warping. The axis is pierced with a small hole which permits of the introduction

of an insulated electrical conductor. This conductor is brought to an insulated terminal at the lower end of the axis through which contact is made by a spring brush and binding post, the other side of the circuit being grounded. This arrangement permits of the use of any suitable source of electric current for the various small bulbs used for lighting cross wires, microscopes, etc., and does away with the mounting of flashlight batteries on the alidade, an objectionable feature of previous instruments used by the Bureau.

The circle plate is of bronze, with a sterling silver ring upon which the graduations are ruled. A smaller circle of coarse, one degree graduations is ruled upon the bronze for a rough setting. The circle, as previously mentioned, is of the floating type in that its bearing is on the outside of the cast iron socket which is also the bearing for the alidade axis. Great care must be taken that this bearing shall be concentric with that of the vertical axis as any considerable lack of concentricity will result in a large difference in the readings of the two micrometers on part of the circle, and make it more difficult to compute the mean value of the readings. The circle is held against its seat by gravity and by a large spring washer and nut.

The standard is in one piece of cast bronze, with ell-shaped sections to give a maximum of rigidity with a minimum of weight. The vertical axis fits tightly in a carefully machined socket in the standard and is held by four large steel screws so that axis and standard are virtually one piece.

The micrometer microscopes are of the design in which the actuating screw is pointed and thrusts against a rigid bearing inside of the micrometer box with the slide reacting against it by virtue of two light tension springs. It has been the experience of the U. S. Coast and Geodetic Survey that this is the most satisfactory of the designs it has tried as the pointed thrust bearing, being inside the box, is protected from dirt and cannot readily be responsible for any endwise motion of the screw due to eccentricities, which would introduce serious errors in the readings. Furthermore, the tension spring reactance is considered to be more sensitive and not liable to cause any irregular jumping of the slide

as may be the case in the use of a compression spring if it shifts position, even slightly.

A unique feature of the micrometer is the use of a graduated drum of glass, either milk colored or clear with a frosted interior (see *Journal of the Franklin Institute* for September, 1927). As all work is done at night in order to minimize the effects of horizontal atmospheric refraction due to heated air currents, this drum, provided with a small electric bulb to light its interior, is very desirable, as the etched and blackened graduations stand out boldly. The intensity of illumination may also be easily regulated so that there need not be as much fatigue of the observer's eye as in the past, due to looking at a faint light and then immediately at a brilliantly lighted micrometer drum.

The alidade clamp and slow motion tangent screw have several unusual features of design. The clamp is mounted on a large thrust ball bearing which practically does away with friction at this point, making pointing of the telescope correspondingly easier and smoother. (Note: The telescope is approximately 45 power and consequently of restricted field of view.) The clamp is of the radial type so that the act of clamping has no tendency to rotate the alidade as in the tangential design. The clamp is very powerful, having a shoe pressed against the braking surface by a thumb screw. Upon release, the screw withdraws the shoe positively so that there is no possibility of drag and friction. The slow motion tangent screw is unique in that it actuates a plunger which does not rotate. This non-rotary feature prevents the irregular motion of the alidade caused by an eccentric point on a rotary tangent screw pressed against the lug on the alidade, and the design lends itself to dust proofing, a valuable feature as the screw must be of fine pitch.

The complete instrument is quite light, weighing but $34\frac{1}{2}$ pounds. It is rugged and easy to adjust, fast in operation and has proven itself to be as accurate as any that have been used by the Bureau. These are the features which were specifically laid down as necessary when the design of the theodolite was taken up as being in their entirety unobtainable in any one commercial instrument. The field results have demonstrated that these requirements have been amply fulfilled.

Ionization in the Upper Atmosphere of the Earth. E. O. HURLBURT. (*Phys. Rev.*, June, 1928.) There are five agencies that may produce ionization in the upper part of the atmosphere of the earth, ionizing radiation from the earth, cosmic radiation and, from the sun, alpha and beta particles and ultra-violet light. The first may be neglected because in the lower strata of the air an increase of distance from the earth is accompanied by an increase of ionization. Cosmic radiation at the surface of the earth produces but few ions and high up where the air is rare it can have little effect. There is no positive evidence that the earth receives alpha and beta particles from the sun, but without any question its ultra-violet radiation does reach the earth.

The author combines theory and the experimental results of others and reaches the conclusion that much of the ionization in the higher part of the atmosphere is due to ultra-violet light of wave-length less than 1200 A. and that on a summer's day most of the ions are produced above the 200 km. level. The sun sends to the earth enough radiation of the effective wave-length to produce 2×10^8 pairs of ions every sec. in an air column 1 sq. cm. in cross-section reaching up from an altitude of 200 km. to the outer limit of the atmosphere. On a summer day the density of electrons so caused is a maximum at a height of 190 km. and amounts to 3×10^5 electrons per cu. cm. "This ionization is shown to explain quantitatively many facts of wireless telegraphy, i.e., the skip distances, overhead absorption coefficients, limiting waves, ranges and the apparent heights reached by waves." The change of wireless signals with hour and season can likewise be explained by the author's theory. The non-polar aurora of Rayleigh is attributed to solar energy stored in the upper air in ionized or excited atoms and set free later as light. G. F. S.

THE EQUATION OF STATE OF A SUBSTANCE AT THE ABSOLUTE ZERO OF TEMPERATURE, AND PROPERTIES CONNECTED WITH IT.

BY

R. D. KLEEMAN, B.A., D.Sc.

§ 1. INTRODUCTORY REMARKS.

In previous papers [1] the writer has determined the zero of the controllable internal energy and entropy of a substance, and some of the corresponding properties. This zero corresponds to the substance being in the condensed state under its vapor pressure at the absolute zero of temperature. The subject is extended in the present paper in connection with the equation of state of a substance at the absolute zero of temperature. It leads to results which can be tested by numerical data. The equation of state thus obtained thermodynamically falls into line with the equation of state of a mixture at any temperature obtained in a previous paper,[2] whose deduction does not depend on thermodynamics.

§ 2. PROPERTIES OF A SUBSTANCE OR MIXTURE IN CONNECTION WITH ITS MAXIMUM WORK AT THE ABSOLUTE ZERO OF TEMPERATURE.

If A denotes the maximum work and p the pressure of a substance or mixture, their relation is given by the well known equation

$$\left(\frac{\partial A}{\partial v}\right)_T = -p. \tag{1}$$

On multiplying it by ∂v and integrating we obtain

$$A = -\int p \cdot \partial v + \phi(T, M_a, M_b, \cdots), \tag{2}$$

where ϕ is an arbitrary function of the temperature and

[1] *J. Phys. Chem.*, 31, 747; 31, 937 (1927): *Phil. Mag.*, 3, 883; 4, 257 (1927); 5, 668 (1928).

[2] J. Franklin Inst., 206, (4), 511 (1928).

masses $M_a, M_b, \cdots$ in mols of the constituents. The maximum work is also given by

$$A = U - TS, \tag{3}$$

where U denotes the internal energy and S the entropy of the substance. On substituting from this equation for A in the preceding equation and differentiating it with respect to M_a at constant volume and temperature we obtain

$$\left(\frac{\partial U}{\partial M_a}\right)_{v,\,T} - T\left(\frac{\partial S}{\partial M_a}\right)_{v,\,T} = -\int\left(\frac{\partial p}{\partial M_a}\right)_{v,\,T}\cdot\partial v + \left(\frac{\partial \phi}{\partial M_a}\right)_{v,\,T}. \tag{4}$$

The left-hand side can be shown to be zero if the substance is under its vapor pressure at the absolute zero of temperature.

We may write

$$\frac{dU}{dM_a} = \left(\frac{\partial U}{\partial v}\right)_T \frac{dv}{dM_a} + \left(\frac{\partial U}{\partial M_a}\right)_v \tag{5}$$

according to the Calculus. Now

$$\left(\frac{\partial U}{\partial v}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_v - p = 0 \tag{6}$$

according to a well-known thermodynamical equation, since $T = 0$ and $p = 0$. The coefficient dU/dM_a expresses the change in internal energy when a mass of the mixture under its vapor pressure is mixed with a mass ∂M_a of the elementary substance a under its vapor pressure, and the resultant mixture is under its vapor pressure. This change the writer has shown is zero at the absolute zero of temperature.[3] It follows therefore from equation (5) that

$$\left(\frac{\partial U}{\partial M_a}\right)_v = 0. \tag{7}$$

From this equation, and since $T = 0$, it follows that the left-hand side of equation (4) is zero or

[3] *J. Phys. Chem.*, 31, 1559 (1927).

$$\left(\frac{\partial A}{\partial M_a}\right)_{v,\,T} = -\int\left(\frac{\partial p}{\partial M_a}\right)_{v,\,T}\cdot\partial v + \left(\frac{\partial \phi}{\partial M_a}\right)_{v,\,T} = 0. \quad (8)$$

This equation may be transformed into a more useful form.

The maximum work has the functional form expressed by the equation

$$A = M_a\cdot\psi_a\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right) + M_b\cdot\psi_b\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right)\cdots + M_a\cdot\xi_a(T) + M_b\cdot\xi_b(T) + \cdots \quad (9)$$

or

$$A = \Sigma M\cdot\psi\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right) + \Sigma M\cdot\xi(T), \quad (10)$$

since it satisfies the condition that if the masses of each constituent and the volume are increased n times under constant pressure the maximum work is increased n times. Equation (2) may therefore be written

$$A = -\int p\cdot\partial v + \Phi(T, M_a, M_b, \cdots) + \Sigma M\cdot\xi(T), \quad (11)$$

where

$$-\int p\cdot\partial v + \Phi(T, M_a, M_b, \cdots) = \Sigma M\cdot\psi\left(T, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right). \quad (12)$$

according to equation (10). On differentiating equation (11) with respect to M_a at constant volume, and applying it to a substance under its vapor pressure at the absolute zero of temperature, it becomes

$$\left[\frac{\partial}{\partial M_a}\left\{-\int p\cdot\partial v + \Phi(0, M_a, M_b, \cdots)\right\}\right]_v + \left(\frac{\partial}{\partial M_a}(\Sigma M\cdot\xi(0))\right)_v = 0, \quad (13)$$

according to equation (8). The two expressions in this equation must separately vanish since M_a, M_b, $\cdots$, are independent variables, and the differential coefficient of the expression within the square brackets is according to equation (12) a function of T, M_a/v, M_b/v, $\cdots$. Hence generalizing we have

$$\left.\begin{aligned} &\frac{\partial}{\partial M_a}\left\{-\int p\cdot\partial v+\Phi(0, M_a, M_b, \cdots)\right\}=0,\\ &\frac{\partial}{\partial M_b}\left\{-\int p\cdot\partial v+\Phi(0, M_a, M_b, \cdots)\right\}=0,\\ &\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot \end{aligned}\right\} \tag{14}$$

when $T = 0$ and initially $p = 0$, where the differentiations refer to the volume and temperature being kept constant.

§3. THE EQUATION OF STATE OF A SUBSTANCE OR MIXTURE AT THE ABSOLUTE ZERO OF TEMPERATURE.

This equation is obtained if a form of the function ψ in equation (12) is found which satisfies equations (14). Let us write

$$\begin{aligned} -\int p\cdot\partial v &+ \Phi(0, M_a, M_b, \cdots)\\ &= v\Sigma\frac{M}{v}\cdot\psi\left(0, \frac{M_a}{v}, \frac{M_b}{v}, \cdots\right)\\ &= v\cdot\psi_1\left(\frac{M_aA_0+M_aB_0+\cdots}{v}\right)=v\cdot\psi_1(x)\cdots \end{aligned} \tag{15}$$

according to equation (12) applied to $T = 0$ and $p = 0$, where ψ_1 is a proposed functional form of $\Sigma(M/v)\cdot\psi$ involving

$$\frac{M_aA_0+M_bB_0+\cdots}{v}$$

written for shortness x, where A_0, B_0, C_0, $\cdots$ are constants. From the first of equations (14) and equation (15) we then have

$$A_0\frac{\partial\psi_1}{\partial x}=0$$

and from the second of equations (14) and equation (15)

$$B_0 \frac{\partial \psi_1}{\partial x} = 0$$

and so on. Thus if ψ_1 the proposed form of $\Sigma(M/v) \cdot \psi$ satisfies one of equations (14) it satisfies each of them. The function ψ_1 has thus the correct *general* form.

The relation between p, v, M_a, $\cdots$ at $p = 0$ and $T = 0$ is obtained on differentiating equation (15) partially with respect to v, which may be written

$$p = \psi_1(x) + v \frac{\partial \psi_1}{\partial v} = \psi_0\left(\frac{M_a A_0 + M_b B_0 + \cdots}{v}\right). \quad (16)$$

This is also the equation of state at $T = 0$ corresponding to various values of p and v, since in general p is a function of M_a/v, M_b/v, $\cdots$ and the general equation of state assumes the foregoing form for a value of v corresponding to $p = 0$. The equation satisfies equations (14) as should be the case. It has a certain characteristic form from which a number of important properties of matter at the absolute zero of temperature may be deduced.

§4. A CHARACTERISTIC CONSTANT OF A SUBSTANCE.

On writing the masses of the constituents equal to zero except M_a in equation (16) it becomes

$$p_a = \psi_0\left(\frac{M_a A_0}{v}\right) \quad (17)$$

and is the equation of state of the pure substance a at $T = 0$. At the absolute zero of control, which corresponds to the substance being under its vapor pressure at $T = 0$, the equation becomes

$$p_{a0} = 0 = \psi_0\left(\frac{M_a A_0}{v_{a0}}\right), \quad (18)$$

where v_{a0} denotes the volume of the substance under its zero vapor pressure p_{a0}. From this equation it follows that

$$\frac{M_a A_0}{v_{a0}} = k, \quad (19)$$

where k is a constant. Similarly it can be shown that

$$\frac{M_b B_0}{v_{b0}} = k \tag{20}$$

and so on. *Thus k is an absolute constant, and is one of the important constants in nature.*

On writing equation (19) in the form

$$A_0 = \frac{v_{a0}}{M_{aa}} k \tag{21}$$

it appears that the characteristic constant A_0 of a substance at the absolute zero of temperature is proportional to the atomic volume v_{a0}/M_a, or the volume occupied by one gram atom, at the absolute zero of control.

§5. THE ADDITIVE NATURE OF THE ATOMIC VOLUMES OF THE CONSTITUENTS OF A MIXTURE AT THE ABSOLUTE ZERO OF CONTROL.

If a mixture is under its vapor pressure at $T = 0$ it follows from equation (16) similarly as before that

$$\frac{M_a A_0 + M_b B_0 + \cdots}{v_0} = k, \tag{22}$$

where v_0 denotes the volume of the mixture under these conditions. On eliminating the masses of the constituents by equations of the type (19) the foregoing equation becomes

$$v_{a0} + v_{b0} + \cdots = v_0 \tag{23}$$

or the volume of a mixture at the absolute zero of control is equal to the volumes the constituents have in the isolated state.

This result is well sustained by the facts. Thus Traube has shown [4] that the volume of a substance in the condensed state at the absolute zero of temperature is equal to the sum of the volumes of the constituents in the isolated state, and that the volume of an atom is proportional to the square root of its atomic weight. This is shown for a number of substances in the Table given compiled from a Table given by

[4] *Physik. Z.*, 667, 1909.

Traube. The second column gives the molecular volumes per mol. of a number of substances obtained by extrapolation by means of Cailletet and Mathias linear diameter law, and the third column gives the ratios obtained by dividing the molecular volumes of a substance by the corresponding sum of the square roots of the atomic weights, which, it will be seen, are approximately constant. Traube deduced from the extensive data he examined that for a mol. of atoms a

$$v_{a0} = 2.6\sqrt{a_\omega}, \tag{24}$$

where a_ω denotes the atomic weight of the atom in terms of that of the hydrogen atom. Since according to Glasson the square root of the atomic weight is approximately proportional to the two-thirds power of N the atomic number, the ratio $v_{a0}/N^{2/3}$ is also approximately constant.

It appears therefore that the characteristic constant A_0 of a substance a is proportional to the square root of its atomic weight, or proportional to the 2/3 power of its atomic number.

The deductions in this paper, which have just received an interesting numerical confirmation, are based fundamentally on equation (7). This equation in turn is based [5] on the controllable internal energy of a substance being zero under its vapor pressure, and that $(\partial S/\partial T)_v = 0$, when $T = 0$, results which were established [6] in a previous paper. These results were deduced theoretically from thermodynamics, and now receive additional numerical confirmation. It may also be noted that the results $c_v = 0$ and $(\partial c_v/\partial T)_v = 0$ deduced previously, where c_v denotes the specific heat at constant volume, depend on the equation $(\partial S/\partial T)_v = 0$.

In a previous paper it was shown [2] that the equation of state of a complex substance at the temperature T has the form

$$p = \psi\left(\frac{M_aA_1 + M_bB_1 + \cdots}{v}, \frac{M_aA_2 + M_bB_2 + \cdots}{v}, \cdots\right),$$

where $A_1, B_1, \cdots A_2, B_2, \cdots, \cdots$ are functions of T. A comparison of this equation with equation (16) shows that when

[5] J. Phys. Chem., 31, 1563 (1927).

[6] J. Phys. Chem., 31, 747 (1927).

$T = 0$ we have

$$\frac{A_1}{r_1} = \frac{A_2}{r_2} = \frac{A_3}{r_3} = \cdots A_0,$$

$$\frac{B_1}{r_1} = \frac{B_2}{r_2} = \frac{B_3}{r_3} = \cdots B_0,$$

etc., where r_1, r_2, $r_3 \cdots$ are numerical constants.

§6. THE RATIO OF VAPOR PRESSURES AT $T = 0$.

Equations (17) and (16) which apply to a mixture and the isolated substance a under their vapor pressures at $T = 0$ may be written

$$p = \psi_0(k), \tag{25}$$

$$p_a = \psi_0(k), \tag{26}$$

by means of equations (19) and (22), and hence

$$p/p_a = 1. \tag{27}$$

Thus though the vapor pressures are zero the ratio of one to the other is finite and equal to unity, and this will evidently hold for any substance and mixture. It follows from this result that substances mix in all proportions at the absolute zero of temperature.

§7. THE PRESSURE AT ANY GIVEN STATE AT $T = 0$.

Equations (16) and (17) which also apply to matter in any state at $T = 0$ may be written

$$p = \psi_0\left(\frac{kv_0}{v}\right), \tag{28}$$

$$p_a = \psi_0\left(\frac{kv_{a0}}{v}\right), \tag{29}$$

by means of equations (19) and (22). Therefore if unit volumes of the substance a and the mixture are considered corresponding to $p = 0$, or that $v_0 = 1$ and $v_{a0} = 1$, the equations of state become the same. Thus as far as pressure and volume relations are concerned all substances and mixtures behave in the same manner at the absolute zero of temperature.

But the densities are not the same. Thus the density ρ_{a0} of the substance a at $p = 0$ and $T = 0$ is given by

$$\rho_{a0} = \frac{\omega_a}{2.6\sqrt{\omega_a}} = \frac{\sqrt{\omega_a}}{2.6}, \tag{30}$$

according to equation (24), and hence increases with the atomic weight. The density of a mixture is given by

$$\rho_0 = \frac{\Sigma n\omega_a}{2.6\Sigma n\sqrt{\omega_a}}. \tag{31}$$

§8. THE COEFFICIENTS OF COMPRESSION AND MASS ADDITION AT $T = 0$.

The coefficient of compression is given by

$$\beta = -\frac{\partial v}{\partial p}\frac{1}{v}. \tag{32}$$

For the two cases whose equations of state are (28) and (29) we have

$$\beta = \frac{1}{\dfrac{\partial\cdot\psi_0\left(\dfrac{kv_0}{v}\right)}{\partial v}}\frac{1}{v}, \tag{33}$$

$$\beta_a = \frac{1}{\dfrac{\partial\cdot\psi_0\left(\dfrac{kv_{a0}}{v}\right)}{\partial v}}\frac{1}{v}. \tag{34}$$

Therefore if masses of the substances are taken so that the volumes v_0 and v_{a0} are equal to one another, the coefficients of compression are the same if the volumes of the substance a and of the mixture are taken equal to each other, and this result therefore holds in general.

The coefficient of mass addition γ, corresponding to the addition of a mass ∂M_a in gram atoms of the substance a, at constant volume, is given by

$$\gamma = \left(\frac{\partial p}{\partial M_a}\right), \tag{35}$$

where M_a denotes the mass in gram atoms, which the substance or mixture contains. By the help of equations (16), (17), (19), and (22) we then have

$$\gamma = \left(\frac{\partial\psi_2(y)}{\partial y}\right)_v \frac{A_0}{v}, \tag{36}$$

$$\gamma_a = \left(\frac{\partial\psi_2(z)}{\partial z}\right)_v \frac{A_0}{v}, \tag{37}$$

where

$$y = \frac{kv_0}{v}$$

and

$$z = \frac{kv_{a0}}{v},$$

for a pure substance a and a mixture. Therefore if masses of matter are considered so that v_0 is equal to v_{a0} the coefficients will be the same for equal volumes of the substance and mixture.

If γ_a denotes the coefficient when the substance a is added, and γ_e that when the substance e is added, to any given mixture whose volume is unity when under its vapor pressure at $T = 0$, we have

$$\frac{\gamma_a}{\gamma_e} = \frac{A_0}{E_0}, \tag{38}$$

§9. THE WORK OF COMPRESSION AND CHANGE IN INTERNAL ENERGY AT $T = 0$

The work ω done in compressing a mixture from its volume v_0 under its vapor pressure to the volume v may be written

$$\omega = \int_{v_0}^{v} p\cdot\partial v = \psi_3\left(\frac{kv_0}{v}\right)\frac{v^2}{kv_0} - \psi_3(k)\frac{v_0}{k}, \tag{39}$$

taking into account equations (16) and (22). Thus the work does not depend on the nature of the mixture but only on its initial and final volume. If equation (6) is multiplied by ∂v and integrated between the same limits the corresponding change in internal energy is obtained. Since $T = 0$ this change is equal to $-\omega$.

§10. THE HEAT AND WORK OF EVAPORATION AT $T = 0$.

If the result of the previous Section is applied to obtain the work performed during the evaporation of a mixture, we have

$$\omega = \psi_3\left(\frac{kv_0}{\infty}\right)\frac{\infty^2}{kv_0} - \psi_3(k)\frac{v_0}{k},$$

which may be written

$$\omega = k_1 v_0 + k_2,$$

where k_1 and k_2 are absolute constants. But ω is zero since it is of the form ΣMRT, and hence k_1 and k_2 are zero. k_1 and k_2 are evidently the limiting values of functions of T when $T = 0$. Therefore if we write the equation in the form

$$\frac{\omega}{k_2} = \frac{k_1}{k_2}v_0 + 1,$$

the limiting values of ω/k_2 and k_1/k_2 are finite. If however we are dealing with an infinitely small mass of the mixture we have $v_0 = 0$ and the limiting value of ω/k_2 is now zero. This reduces the foregoing equation to $0 = 1$, which is absurd. Hence the quantity k_2 must be neglected in comparison with the quantities ω and $k_1 v_0$, which reduces the equation to

$$\omega = k_1 v_0. \tag{40}$$

On considering the evaporation of the isolated constituent a we have

$$\omega_a = k_1 v_{a0}. \tag{41}$$

This and the preceding equation give

$$\frac{\omega}{\omega_a} = \frac{v_0}{v_{a0}} \tag{42}$$

or the ratio of the works of evapoartion, which is a finite quantity.

In a previous paper[7] it is shown that

$$L + \omega = 0, \tag{43}$$

[7] J. FRANKLIN INST., 206, (5), 691 (1928).

where L denotes the internal heat of evaporation. For a mixture and a pure substance a we have from equations (43) and (42)

$$\frac{L}{L_a} = \frac{v_0}{v_{a0}}, \tag{44}$$

which gives the ratio of the internal heats of evaporation. This ratio is of importance since in the paper quoted it is shown that the heat of evaporation is zero.

§11. THE ZERO OF THE INTERNAL ENERGY OF A SUBSTANCE OR MIXTURE UNDER CONSTRAINT.

Suppose that a substance or mixture is subjected under all conditions to a constraint such as a constant magnetic field, or a constant electric field. It can easily be shown that the zero of internal energy under these conditions corresponds to the substance or mixture being under its vapor pressure at the absolute zero of temperature, as is the case when there is no constraint acting.[6] It can also be shown similarly as when no constraint is acting,[5] that no change in internal energy takes place on mixing the substances under their vapor pressures at the absolute zero of temperature. Hence the particular internal energy due to the field is not changed on mixing. The internal energy U can also be shown to possess the property that

$$\frac{dU}{dT} = 0, \tag{45}$$

$$\frac{d^2U}{dT^2} = 0, \tag{46}$$

Since these equations also hold when the substances are not subjected to a constraint,[8] they hold also for the particular internal energy due the presence of a constraint. By means of these results additional properties of substances at $T = 0$ may be deduced.

§12. MAGNETIC PROPERTIES.

According to the preceding section no change takes place in the magnetic energy, or in the part of the internal energy

[8] *J. Phys. Chem.*, 31, 937 (1927).

due to the presence of the magnetic field, on mixing a number of substances in a magnetic field of strength H at $T = 0$. Hence if two substances a and e of permeability μ_{a0} and μ_{e0} are mixed, giving rise to a mixture of permeability μ_{ae0}, we have

$$\frac{H^2\mu_{ae0}v_0}{8\pi} = \frac{H^2\mu_{a0}v_{a0}}{8\pi} + \frac{H^2\mu_{e0}v_{e0}}{8\pi}$$

or

$$\mu_{ae0}v_0 = \mu_{a0}v_{a0} + \mu_{e0}v_{e0}. \tag{47}$$

We also have

$$v_0 = v_{a0} + v_{e0}, \tag{48}$$

according to Section 5, where v_{a0}, v_{e0}, and v_0 denote respectively the volumes of the constituents and of the mixture under their vapor pressures at $T = 0$. Thus the permeability of the mixture at the absolute zero of temperature can be calculated from the permeabilities of the constituents by means of the foregoing two equations.

The particular internal energy of a substance which does not depend on its volume and temperature is the internal energy possessed by the substance under its vapor pressure at $T = 0$. Hence the magnetic internal energies $H^2\mu_{ae0}v_0/8\pi$, etc., at $T = 0$, are parts of the corresponding magnetic internal energies of the substances at T which do not change with v and T, but which disappear when the magnetic field is removed.

If μ_a, μ_e, and μ_{ae} denote the permeabilities corresponding to any volume and temperature the magnetic internal energies $H^2\mu_{ae}v/8\pi$, etc., satisfy equations (45) and (46). Hence

$$\frac{d\mu_{ae}}{dT} = 0. \tag{49}$$

$$\frac{d^2u_{ae}}{dT^2} = 0, \tag{50}$$

for the mixture at $T = 0$, since[8] $dv/dT = 0$ and $dv^2/dT^2 = 0$, and similar equations hold for the constituents a and e. The relations (47), (48), (49), and (50) could be tested experimentally by extrapolating magnetic measurements down to $T = 0$.

§13. PROPERTIES OF INDUCTIVITY.

If the substances in the preceding Section were subjected to an electric field of intensity ρ instead of a magnetic field similar conclusions would hold. We would then have

$$\frac{2\pi\rho^2 v_0}{K_{ae0}} = \frac{2\pi\rho^2 v_{a0}}{K_{a0}} + \frac{2\pi\rho^2 v_{e0}}{K_{e0}}$$

or

$$\frac{v_0}{K_{ae0}} = \frac{v_{a0}}{K_{a0}} + \frac{v_{e0}}{K_{e0}}, \tag{51}$$

where K_{ae0}, K_{a0}, and K_{e0} denote the inductivities of the mixture and isolated constituents respectively at $T = 0$. As before we have besides

$$v_0 = v_{a0} = v_{e0}, \tag{52}$$

By means of the foregoing two equations the inductivity of the mixture may be calculated from the inductivities of the constituents.

It can now easily be shown similarly as in the preceding Section that

$$\frac{dK_{ae}}{dT} = 0, \tag{53}$$

$$\frac{d^2K_{ae}}{dT^2} = 0 \tag{54}$$

for the mixture at $T = 0$, and that similar equations hold for the isolated constituents.

§14. MIXING SUBSTANCES UNDER A PRESSURE p AT $T = 0$.

Consider a number of substances under the same external pressure p at $T = 0$. From equations (28) and (29) it follows that the corresponding volumes are the same fraction α of their volumes at $p = 0$. The work done on compressing a mixture from the pressure 0 to p is

$$\omega = \left\{\psi_3\left(\frac{k}{\alpha}\right)\alpha - \psi_3(k)\right\} v_0 \tag{55}$$

according to equation (39). Since v_0 is equal to the sum of

the volumes of the isolated constituents at $p = 0$ and $T = 0$ according to equation (23), the above work is equal to the sum of the work of compressing the isolated constituents. A similar result holds for the changes in internal energy. Hence, since the work of mixing a number of substances, and the corresponding change in internal energy, at $p = 0$ and $T = 0$, is zero, this will also hold if p has some finite value. This can easily be demonstrated by passing the mixture through a cycle using the foregoing results.

§15. THE RADIATION PROPERTIES OF SUBSTANCES AT $T = 0$.

TABLE

Substance		v_0	$v_0/\Sigma n\sqrt{\omega_a}$
Iodo benzene	C_6H_5I	89.9	2.4
Chloro benzene	C_6H_5Cl	79.0	2.5
Fluor benzene	C_6H_5F	70.6	2.3
Bromo benzene	C_6H_5Br	82.2	2.4
Stannic chloride	$SnCl_4$	87.0	2.5
Carbon tetrachloride	CCl_4	72.7	2.7
Titanium trichloride	$TiCl_3$	85.8	2.8
Phosphorous oxychloride	$POCl_3$	70.1	2.6
Arsenic trichloride	$AsCl_3$	65.4	2.3
Ethyl sulphide	$C_4H_{10}S$	80.8	2.7
Benzene	C_6H_6	66.4	2.5
Octane	C_8H_{18}	123.5	2.7
Tentane	C_5H_{12}	80.7	2.7
Ethyl ether	$C_4H_{10}O$	72.6	2.6
Acetone	C_3H_6O	53.2	2.6
Ethyl acetate	$C_4H_8O_2$	72.6	2.4
Sulphur dioxide	SO_2	31	2.3
Carbon dioxide	CO_2	25.5	2.2

Suppose that the substances a and e and the mixture that may be formed of them are subjected to a radiation of intensity I, and let P_a, P_e, and P_{ae} denote the radiation pressures respectively exerted on them per cm². On mixing the substances a and e at $T = 0$ no external work is done according to Section 14, and hence

$$P_{ae}v_0 = P_a v_{a0} + P_e v_{e0}. \tag{56}$$

Since

$$\left.\begin{aligned} P_{ae} &= \tfrac{1}{3}a_{ae}\mathrm{I}, \\ P_a &= \tfrac{1}{3}a_a\mathrm{I}, \\ P_e &= \tfrac{1}{3}a_e\mathrm{I}, \end{aligned}\right\} \tag{57}$$

where a_a, a_e, and a_{ae} denote the absorbing powers of the substances a and e and of the mixture respectively, equation (56) may be written

$$a_{ae}v_0 = a_a v_{a0} + a_e v_{e0}. \tag{58}$$

Besides we have the equation

$$v_0 = v_{a0} + v_{e0}. \tag{59}$$

From these two equations the absorbing power of the mixture at $T = 0$ may be expressed in terms of the absorbing powers of the isolated constituents. The foregoing results will evidently hold independently of the nature of the radiation.

SCHENECTADY, N. Y.

THE PROGRESS OF 220 K.V. DEVELOPMENT.

BY

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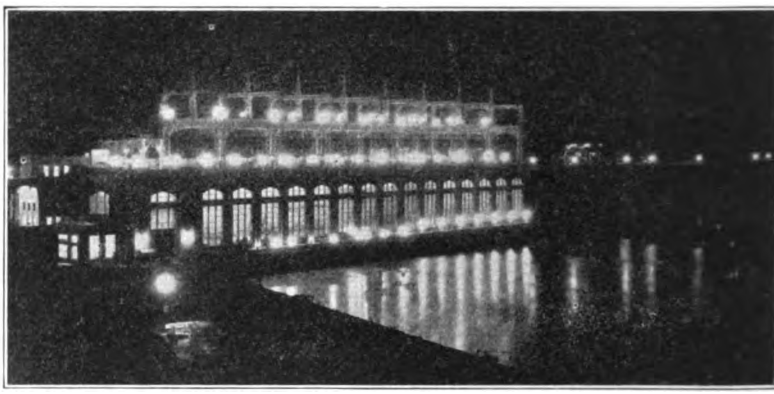
"THERE are no bounds (but what expense and labor give) to the force men may raise and use in the electrical way," said Benjamin Franklin in his work entitled "New Experiments and Observations on Electricity."

It was in Philadelphia that the idea of transmitting electricity over a distance was first conceived, and Franklin thus describes his epoch-making experiment: "Two iron rods about 3 feet long were planted just within the margin of the Schuylkill River on the opposite sides. A thick piece of wire with a small round knob at its end was fixed on the top of one of the rods bending downwards, so as to deliver commodiously the spark upon the surface of the spirit. A small wire, fastened by one end to the handle of the spoon containing the spirit, was carried across the river and supported in the air by the rope commonly used to hold by in drawing ferryboats over. The other end of this wire was tied around the coating of the bottle, which being charged the spark was delivered from the hook to the top of the rod standing in the water on that side. At the same instant the rod on the other side delivered the spark into the spoon and fired the spirit. The electric fire returned to the coating of the bottle through the handle of the spoon and the supported wire connected with them."

Today Philadelphia is supplied with power from the largest interconnected power system in the world employing 220 kilovolt equipment. Benjamin Franklin, who first conceived the possibility of electricity being sent to distant points, speaks of the proposed experiments of "sending electric fire (electricity) through a vast length of space." One hundred and seventy years later we find the country provided with isolated power systems and a new industry of power production created. Individual systems are now in existence using steam or hydraulic prime movers and employ-

ing transmission from 22,000 up to 220,000 volts. Today electric power is essential to production of raw material and is a powerful aid in transportation, also in the utilization of products of industry. The electric system is in itself a complete unit for the production, transmission and distribution of energy. It may be said that a nation's civilization can be largely measured in terms of k.w. hours consumed per capita, for as the electric energy consumption is large so the inefficient human labor energy will be small.

Fig. 1.



Conowingo Station. Night view looking north showing power house 220kv substation and west portion of dam.

Ideas conceived one hundred and seventy years ago as a possibility, when little was known of the newly discovered phenomenon—electricity—have become not only a reality but a matter of necessity. The trend of electrical development was foreshadowed by Franklin in his early experiments. He says, "We fire spirits, we light candles, we represent lightning, we electrify a person, we melt gold, silver and copper in small quantities by the electrical flash. We have frequently given polarity to needles and reversed it at pleasure. We demonstrate the afflux and efflux of electrical fire by means of a little light windmill turning on a fine wire axis, also by little wheels formed like water wheels, of the disposition and application of which wheels, and the various phenomena resulting I could, if I had time, tell you

a sheet." Today we have learned how to use this stupendous force whose harness is a wire and whose checkrein is a switch —a force that can drive trains, dredge a harbor, flood the night sky with light, cut a steel beam as if it were paper and warm the baby's milk. We can safely assume that electric power developed all over the country will finally make power service universal. It is therefore the duty of the electrical engineer to plan the system some time ahead, and not to allow it to grow without a general plan.

The tendency in the past was to construct power systems radiating from large central stations and to interconnect the lines of the different systems where they met. Such a procedure would not satisfy the needs of the future power industry with its large units and stations, its tremendous power resources and markets. The conclusion as to what course is best for the power industry is the same as that which is best for the country as a whole. It is evident that fuels, particularly oil, must be used for power only where hydro-electric power is not available as, e.g., in the propelling of air and ocean craft. The best course for the power industry., therefore, is the use of natural water power resources as far as is practicable for the purpose of conserving human energy and fuels. This will add to the stability of the power industry and bring about the development of water powers, which, transmitted to cities and industries, would operate in conjunction with large efficient steam power plants.

A comprehensive outline of interconnection of all the present existing power systems in the United States by means of 220 k.v. transmission lines was developed by F. G. Baum in 1923. It was the interconnected system of the Philadelphia Electric Co., the Pennsylvania Power & Light Co. and the Public Service Gas & Electric Co. of New Jersey which has made the first link in the scheme proposed by Baum. Yet the credit for the pioneering development of the 220 K.V. equipment must be given to the State of California.

It happens that the natural conditions in California are such as to have forced extensive water power developments and transmission. The location of sources of power being east of the large central valleys made it necessary to build transmission lines across and through the valleys in order

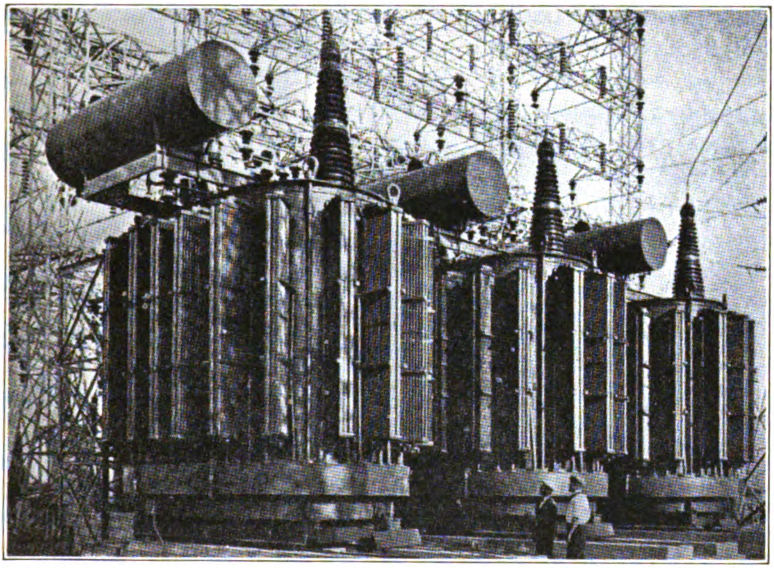
to reach the large industrial power markets and cities near the seacoast. The population on the Pacific coast is rapidly increasing, especially in the large cities, and their environs, and certain other districts where there is good land for food production, and irrigation is feasible. In respect to power supply, the Pacific coast states are fortunate because of the abundance of water power and of fuel oil for steam power. One authority states these water powers may have an ultimate development of 18,000,000 k.w. The supplied population is in the neighborhood of 5,000,000 and the electric power consumption per inhabitant is 0.25 k.w., the highest for the nation. Climate, topography and irrigable fertile soil are the great factors that determine the localities where people want to live. Rain or snow at high elevations determine the location of water powers. The result is that great distances occur between water power sources and markets. The increased transmission voltage greatly stimulated the development of water power in the mountains, the power being transmitted to cities and industries.

About 1908 transmission voltages of 100,000 were used and these have since been increased to 165,000 in the case of the Caribou-San Francisco line of the Great Western Power Co. In most of these installations the distance of transmission was not over 150 miles and amounts of power transmitted were limited to 25,000 k.w. per line. Because of the economic supply of fuel oil everywhere throughout the Pacific coast areas steam power stations can always be located at or near their corresponding markets, involving only short distance power transmission. Compared with steam power, unit hydroelectric power investment costs are high and operating maintenance and depreciation costs are low. The supply of hydroelectric power is subject to seasonal and annual fluctuation wholly without relation to demand. Steam power can supply demand at all times. A large part of the k.w. hours per annum required could therefore be furnished from water power, the balance being supplied more economically from steam power consumed as daily peak loads and to make up for water power deficiencies during periods of minimum stream flow.

The Southern California Edison Co. was the first to be

confronted with the problem of application of 220 k.v. Of the two alternatives, whether to build new transmission lines from their Big Creek System to Los Angeles or to change over the present 150 k.v. equipment to 220 k.v. the latter method was chosen as more economical. At the same time it was clearly understood that development of trunk transmission at 220 k.v. would involve new problems arising

Fig. 2.



Typical arrangement of the Great Western Power Company switching equipment.

from the high voltage, the large amount of power transmitted and the high service standards which the importance of the transmission would demand. An experimental line at 235 k.v. was equipped by the Southern California Edison Co. over a distance of seven miles proving the feasibility of successful operation. The new record 165 k.v. Caribou Line was then outdone by the greater feat of constructive imagination in changing the Southern California Edison Co. high lines to 220 k.v., shortly followed by the Pit River Line of the Pacific Gas & Electric Co.

It soon become evident that the existing power systems

should be interconnected to permit practically unlimited exchange of energy. A proposal to interconnect the California transmission systems through a great bus extending nearly the length of the State was outlined in a paper by R. W. Sorenson, H. H. Cox and G. E. Armstrong, read at the Pacific Coast Convention of the A. I. E. E. It proposed 1,100 miles 220 k.v. transmission bus of standard frequency, 60 cycles, in the belief that the Southern California Edison Co. Power System operating at 50 cycles would ultimately find it advantageous to conform to the A. I. E. E. standards. Such change has not been made as yet, instead frequency changing sets are being installed to permit the exchange of energy between the adjacent power systems. The calamity resulting from a drought in 1924 taught the "sunny South" a bitter lesson of the vital importance of interconnection. Two gigantic steam power plants and a large frequency changing station were built as a result of this memorable experience. Southern California recently had another opportunity to appreciate the value of interconnection when the failure of the St. Francis Dam occurred. The destruction of one of the power houses and failure of the transmission line put the entire power system of the Bureau of Power and Light in Los Angeles temporarily out of commission. The entire load was quickly assumed by the Southern California Edison Company whose system is now provided with an adequate steam reserve.

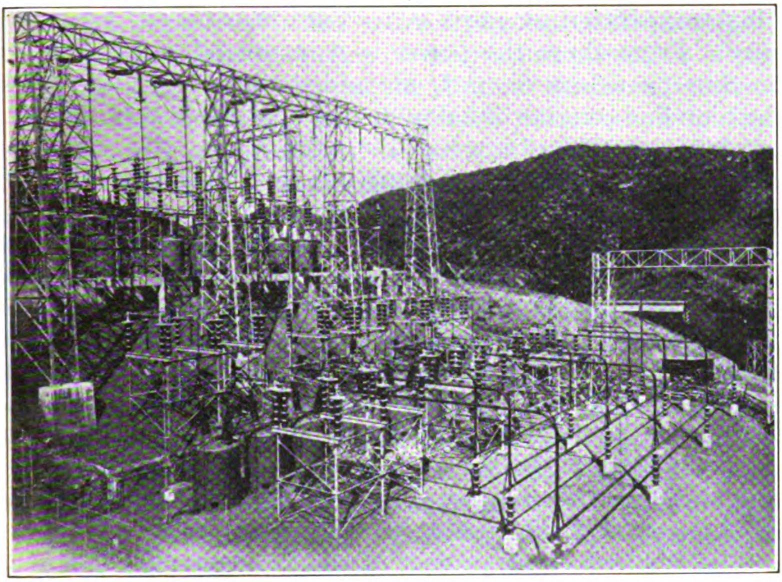
EQUIPMENT.

Factors which are practically negligible in the design of lower voltage switching equipment become of paramount importance in the design of stations for 220 k.v. operation. Perhaps no item in connection with electrical development of recent years has increased in greater proportion than the high voltage switching stations. All the existing 220 k.v. switching stations are of the outdoor type and there is very little probability in the future of a return to the indoor type arrangement. The space requirements for the switching of a double circuit line have increased from a few thousand square feet to more than a hundred thousand square feet. For example the Lighthipe Substation covers 30 acres, while Plymouth Meeting is laid over a tract of forty acres.

We shall now consider the existing 220 k.v. systems in the order of their installation.

The power system of the Southern California Edison Co. consists of a major group of hydroelectric plants, located in the Sierras, utilizing the waters of the Big Creek and San

Fig. 3.



Typical arrangement of the Southern California Edison Company Equipment.

Joaquin Rivers. The Big Creek power houses have been built to transmit power at 220 k.v. to Los Angeles—a distance of 250 miles. Two large receiving substations, Eagle Rock and Laguna Bell, terminating the two lines from Big Creek System, have been recently augmented by a third line and the additional Lighthipe Substation, tying the high lines with the general system and the newly constructed steam plant at Long Beach. There are two intermediate switching stations at Vestal and Magunden, located along the initial double circuit high lines, which are used for sectionalizing and cross connecting the lines. The Vestal Station also serves as a tie with adjacent utilities controlled by the same company. There is also a group of smaller

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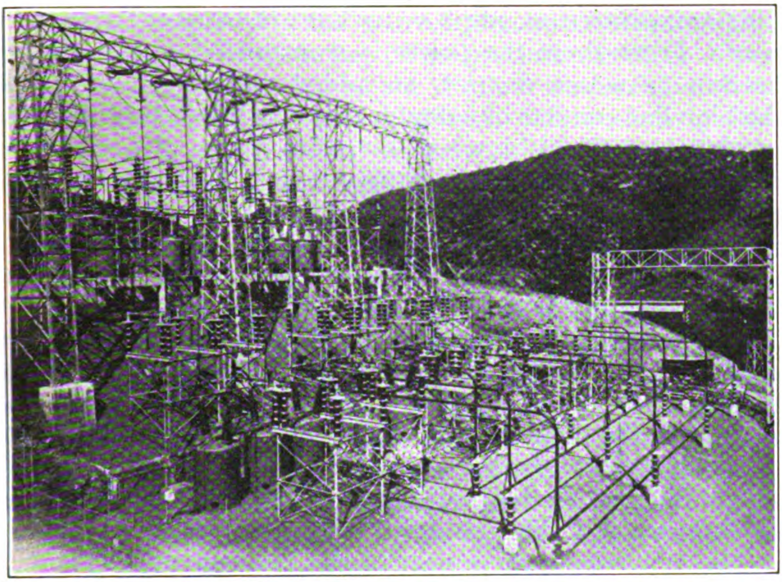

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power stations located on the territory near the center of distribution. The frequency of the system is 50 cycles, 60 cycles being used on the subsidiary Mt. Whitney power system. The large blocks of power are distributed at 66 k.v.

The Pacific Gas & Electric Co. Power System consists of a major group of hydroelectric plants in the Sierras utilizing the waters of the Pit River and its tributaries, the power being transmitted at 220 k.v. to Vaca Substation, 150 miles away. From there the power is transmitted at 110 k.v. to the San Francisco district, an added distance of 60 miles. The high line consists of a double circuit without intermediate switching stations between Pit and Vaca, the standard frequency, 60 cycles, being employed throughout the system. A 110 k.v. tie is made with the adjacent power system of the California-Oregon Power Co.

The two large utilities in Central California—the Great Western Power Co. and the San Joaquin Light & Power Corporation are interconnected at present by means of 220 k.v. lines from Wilson Substation to Brighton, a distance of 105 miles. This connects the Feather River plants with the system of the San Joaquin Light & Power Corporation. These high lines operate at present at 165 k.v., 60 cycles being employed by both systems. This covers the 220 k.v. development in California up to the present time.

The Wallenpaupak project of the Pennsylvania Power & Light Co. employs 220 k.v. transmission from its recently built hydroelectric station to Siegfried Substation, 70 miles distant. This substation in turn is being tied with Plymouth Meeting, of the Philadelphia Electric Co., Roseland, of the Public Service Gas & Electric Co. of New Jersey, and the steam power plant at Sunbury, Pa.

The latest project employing 220 k.v. is the Conowingo plant, in Maryland, utilizing the water power of the Susquehanna River, this energy being transmitted to Plymouth Meeting by means of three high lines. This project was justified economically as the load of the Philadelphia Electric Co. System became sufficiently large to absorb nearly the entire output of the plant at all times. The interconnection between the Philadelphia Electric Co. and the two adjacent power systems belongs to the trunk line class of intercon-

nection as it is intended to facilitate the transfer of large amounts of energy.

The Plymouth Meeting Substation of the Philadelphia Electric Co. is located 65 miles from Conowingo, 49 miles from Siegfried and 77 miles from Roseland. Its 220 k.v. lines are employed for interconnection with the adjacent power systems, and 66 k.v. lines tying with the steam power plants in Philadelphia and vicinity. Standard frequency, 60 cycles is being used in the entire interconnected system.

Although extensive studies of design and operation of the existing 220 k.v. systems in the United States have been made by engineers of other countries this equipment has not been used commercially outside of the United States. However tentative projects are being considered in France and Russia.

From the foregoing it is evident that each of the companies employing 220 k.v. had to meet different conditions and cope with new problems continually. A close study of the individual systems reveals that the engineering staff of the Pacific Gas & Electric Co. displayed originality and radical ways of solving all new problems. Other companies followed the established routine and methods used on their low voltage equipment, with the exception of the Philadelphia Electric Co. The latter, benefiting by the experiences and unavoidable mistakes of other systems, ventured the introduction of many new features.

A glance at the map shows that the distances of transmission circuits employed in California are above 100 and below 300 miles, while in the Eastern group of lines the distance between large power centers ranges from 50 to 100 miles.

The bus is supported either on a steel structure, latticed steel poles or concrete posts. Insulator posts composed of a single or double stack of pillar insulators have been used recently, quadrupedal insulator supports having been used only on the earlier installations. Four inch copper tubing or iron pipe is being used on the double bus installations, the double bus system predominating. Branch bus bars are welded or clamped to the main bus and stiffened at the point of attachment by knee braces on each side of the branch.

Provision for expansion is made on all long bus spans, flexible connection being frequently employed for current carrying purposes. The single bus is used on the Pacific Gas & Electric Co. system, employing by-pass switches which enable continuous operation when the circuit breaker is disconnected for repairs or inspection.

Aluminum cable with steel core is used for line conductors as the most suitable type of conductor considering long spans and corona losses. Two circuits per line are commonly used although three circuits have been recently employed.

A great variety in types of transmission towers used is due to different topographic and climatic conditions of the territory. The single circuit towers with horizontally spaced conductors prevail, while double circuit towers are used in the valleys. A radical departure from the general practice is made by the Pennsylvania Power & Light Co. which employs guyed mast type of structure at angles and dead end points of the line where overturning loads on the towers must be carried constantly. This type of tower has been frequently used with success on the European installations but it may present difficulties in case of the necessity of using a ground wire on the line. The power is interrupted and synchronizing is carried out on the high tension side.

The disconnecting switches are the determining element in the design of the outdoor structure. It may be safely said that there are as many types of switches employed as there are 220 k.v. stations in operation and new types are being developed continually. Gang operated switches are used almost exclusively with manual or motor mechanism, the cantilever, carriage, tilting insulators and rotating insulator type switches with or without grounding attachment being installed on the existing systems.

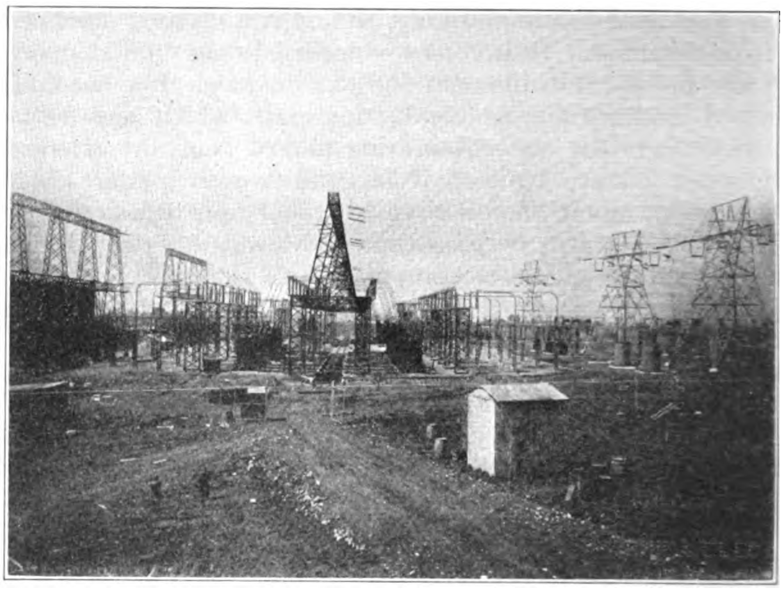
In a 220 k.v. power system where a very great amount of energy is transferred any change of current conditions requiring a sudden change of energy is liable to be destructive. One is easily convinced of the truth of this when one observes the results of a short circuit on a high line or a blow-up of an oil circuit breaker. The requirements of correct system operation demand oil circuit breakers that will not only clear the fault successfully but accomplish this safely in a minimum of

time. Operating experience over the last five years has definitely shown that if trouble is cleared within a certain minimum time little if any burning will result. The rating of the 220 k.v. oil circuit breakers used on one of the latest installations was 2,500,000 k.v.a. interrupting capacity. Direct current is generally used for the operation of breakers. In its present form, the oil circuit breaker is by far the weakest link in the high tension transmission system. Mineral oils with a relatively high flash point are the generally used insulating medium of the present breakers. It must be noted however that during the time of arcing, the oil is a decided detriment to the breaker. It becomes volatilized and builds up excessive pressures in the container, at the same time becoming ionized and forming a conducting path which aids rather than hinders the arc. Requiring almost constant attention and maintenance to keep it in condition to render service when called upon, the oil circuit breaker fails occasionally in its duty. The fact remains that with everything in its favor the service it renders as compared with that given by other classes of equipment is not nearly proportionate to its cost and the care required in its selection and subsequent upkeep. An interesting current interrupting device in the form of the vacuum switch, under experiment at the California Institute of Technology, has appeared recently. While development has not yet reached the point of commercial application the prospects seem encouraging.

The development of transformers indicates a tendency towards larger sizes and more complicated design. Single phase Y connected units with solidly grounded neutrals on the high side are generally used. The early capacity of 50,000 k.v.a. per bank has now reached 130,000 k.v.a. largely due to the application of air jet radiator cooling. Self cooled, water cooled and a combination of self and forced air cooling have been used on the existing installations. Three winding type transformers are employed most frequently. The tertiary winding, being delta connected, provides a path for the third harmonic present in the voltage wave, thus avoiding high insulation stress. Tertiary and quarternary delta connected windings are sometimes used for synchronous condenser starting and operating, also to absorb

the triple frequency exciting current. The use of low voltage taps on the transformer windings for starting the condenser is not so popular since it results in a higher ratio of the bank during starting than that obtained while the condenser is running. This upsets the balance between the current transformers used on the high and low side of the bank for differential protection. The latest installations employ equipment with tap changing under load. The use of transformers with variable ratio

Fig. 4.



Plymouth meeting. General view of substation looking southwest.

introduces a flexibility in operation which permits the division of wattless currents between stations independent of voltage held at the generator busses. Single phase auto transformers rated 36,700 k.v.a. each have been used on the early installation of the Southern California Edison Co. when a change was made from 150 to 220 k.v. operation. An interesting feature is that these auto transformers are tied in solid with the transmission lines and form an integral part of it. They are the largest auto transformers in existence.

Bushing type current transformers are used on the oil

circuit breakers and power transformers. No other type of metering transformers has been used so far except on the latest installation at Plymouth Meeting where the Conowingo lines are equipped with high voltage potential transformers and the lines connecting with the adjacent systems are equipped with 220 k.v. metering equipment.

On long distance transmission of large amounts of power stability is the controlling feature. Synchronous condensers are generally used at the end of transmission lines for stabilizing voltage and affording power factor correction. On long lines at high voltages the charging current at no load, being a leading quadrature current, causes a voltage rise over the line when flowing over the reactances found in its circuit. At heavy loads the power current causes a voltage drop flowing over resistances and reactances in the circuit. Thus by introducing at no load a lagging quadrature current, voltage rises may be compensated for, and by introducing at a heavy load a leading quadrature current, voltage drops may be compensated for. Synchronous condensers therefore are valuable in increasing the power capacity of transmission lines, adding to stability, and allowing a simplified method of voltage regulation by the system operator. The size of condensers recently installed is 50,000 k.v.a. as compared with the 20,000 k.v.a. of the early type. A new method called quick response excitation has been employed in the recent installations. It requires an auxiliary exciter for the field of the main exciter, the latter being therefore a separately excited machine. A new regulator, unique in its operating characteristics, has been developed which makes it possible to sustain stable operation under condition of dynamic stability, thus increasing the maximum power by taking advantage of a heretofore unexploited range of operation of synchronous machines. The object of a quick response excitation system is to build up rapidly a voltage across the field winding of a synchronous machine, to provide sufficient additional magneto-motive force to neutralize the demagnetizing action of the short circuit current flowing in the armature winding.

Protective relays on any extensive transmission system play fully as important a part in the rendering of continuous

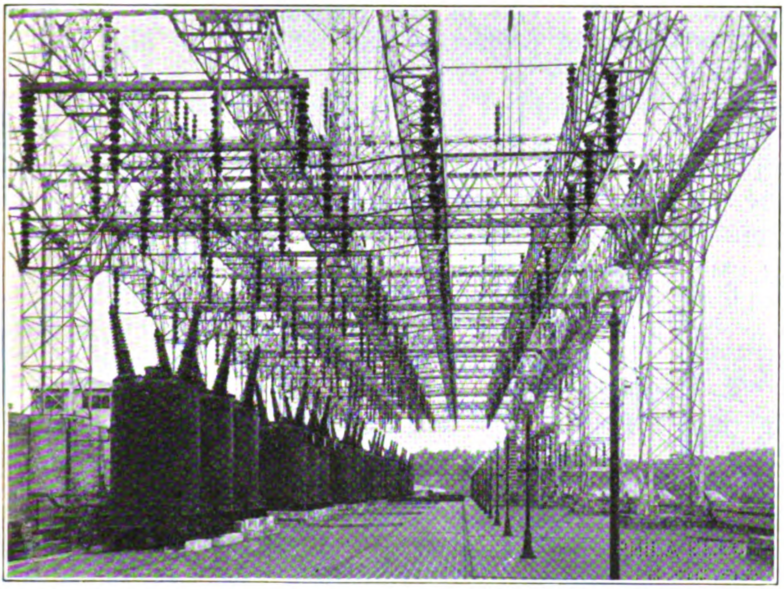
satisfactory service as any other class of apparatus on the system. Being automatic and selective they are infinitely quicker and more accurate than the average good operator, requiring little attention on his part. The interconnection of large power systems requires special treatment of its protective relay installation in order to secure proper automatic sectionalizing. It must be such that the power loads supplied to the line or taken from the line may vary, that the flow of power over sections may be actually reversed without disturbing the voltage regulation necessary to give good service at all points. Interconnection therefore between large power units imposes more strenuous demands on the relay protective equipment than do individual systems, even those of a large size. The most important requirement is that all the faults be cleared quickly, thus preventing unnecessary burning of conductors and equipment and minimizing the possibility of the system becoming unstable. It must allow flexibility of system operation and perfect protection when any line or piece of equipment is cut out of service, without change in relay adjustment when a large unit of power is entirely removed.

A great variety of protective schemes has been used on the existing 220 k.v. systems. The balanced relay protection, with an automatic arc suppressor cutting in resistances in the field of generators and condensers, operated by the neutral ground relays, has been used by the Southern California Edison Co. The prevailing scheme on the other systems is the one employing directional power overload and directional residual relays. Impedance relays are being used on the latest installations and a novel system of transmission line protection by means of carrier current pilot system has been experimented with recently. A comprehensive view of the matter produces the impression that the entire problem of relay protection of the 220 k.v. interconnected systems is still awaiting solution.

The problem of lightning protection is perhaps as old as our knowledge of electricity itself. Benjamin Franklin writes of "thunder gusts and sudden storms of thunder and lightning which are frequently of short duration but sometimes produce mischievous effects." He conducted numerous

experiments in which his life was endangered, trying to investigate the nature of the phenomena and to find means of protection against them. This problem is still a matter of continuous investigation in Europe and in the United States and the development of the Cathode ray oscillograph, clydonograph and the high speed photographic camera have greatly assisted in clarifying certain problems pertaining to the nature of lightning. These "mischievous effects" prove

Fig. 5.



Conowingo Station—General view of 220 kv substation. Elevation 121.6′. Looking northeast.

to be a matter of serious consideration where transmission lines and outdoor substations are subject to frequent and severe lightning. The investigation of lightning surges indicates that the highest of lightning voltages exceeds the strength of any insulation in use at this time. If it were possible to by-pass the lightning voltage surge to ground without the power arc following the by-pass, we would have a very satisfactory method of getting rid of the surge. In the case of line and switch gear insulation some reasonable dependence on the upper limit of insulation strength may

be considered. Insulation within such apparatus as transformers, however, is quite different. Failure in this case usually occurs by puncture. It is quite conceivable that a transient voltage not high enough and not long enough to cause failure would cause a partial failure and if repeated may cause a partial puncture followed by destruction of the insulation. It appears therefore to be a matter of paramount importance to protect properly the apparatus in the substation. Previous experience has indicated that different types of lightning arresters in connection with choke coils installed at each end of the transmission line provide a reliable means of protection and relief. The high cost of lightning arresters for 220 k.v. lines caused serious investigation into the subject of their effectiveness. As a result, none of the existing 220 k.v. systems has employed lightning arresters except the latest installations at Conowingo and Plymouth Meeting. On account of the great extent of the transmission line as compared to the station, it is reasonable to expect that a very large share of the disturbances will originate on the line and can reach the station only by traveling along the line. The line insulation thus constitutes an upper limit for voltages which may reach the station.

As a rule the lower the line the less its susceptibility to lightning. For obvious reasons, a 220 k.v. line cannot be brought very close to earth, therefore some method of bringing an artificial earth close to the wires may prove effective in providing lightning protection. Ground wire has therefore been installed on most of the existing k.v. lines. The practice with respect to the latter is not recognized generally. Some of the companies employ no ground wires while others use as many as two ground wires per circuit. The matter of lightning therefore offers a rich field for further practical investigation and scientific research.

INSULATION.

Since a very large amount of power can be transmitted at 220 k.v. over long distances it is questionable whether higher voltages will be required for a national transmission system. The insulation, as the most vulnerable element of the high voltage development, is a matter of the greatest importance,

its deterioration being the most rapid. It may be said that the length of life of a high voltage system is that of its insulation. Our knowledge of the behavior of insulating materials under variation of voltage, frequency, temperature, humidity and mechanical stresses is very meager, hence insulation in its present form is the least susceptible to exact computation and design. The present methods of control of the important properties of insulating materials, singly and in combination, are very imperfectly developed. As a consequence when designing insulation for 220 k.v. equipment more than liberal provisions are made against these uncertainties, allowing large factors of safety and thus resulting in large sizes and high cost of equipment. Matter in all physical states must be considered in discussing material used for installation —solid insulation such as porcelain and fibrous compounds, liquid insulation such as oil, and gaseous such as air. The latter always appears in connection with solids and therefore plays a vital rôle in the problem of insulation.

The dielectric properties of air were already known in the earlier stage of electrical science. Benjamin Franklin, speaking of the air, says "It assists in confining the electrical atmosphere to the body it surrounds and prevents its dissipating. Air is an electric per se and when dry will not conduct the electrical fire" (meaning electricity). We have discovered since that the effect of placing any insulating body into the static field which exists between two conductors, as represented by a transmission line wire or bus and grounded insulator bracket, is to increase the stress in the air path at the surface of the conductor and the surface of the insulating body. Certain phenomena which were unnoticed because of their feeble effect when low voltage insulation was considered, with the application of 220 k.v. caused a greater energy density, becoming therefore a controling feature. Conductor sizes of a transmission line, calculated according to the previous methods, produced the so-called corona effect resulting in loss of electric energy. It soon became evident that it is much more important to design the dielectric circuit for proper flux distribution than the magnetic circuit, since local overflux density in the magnetic circuit may only cause losses, while in the case of

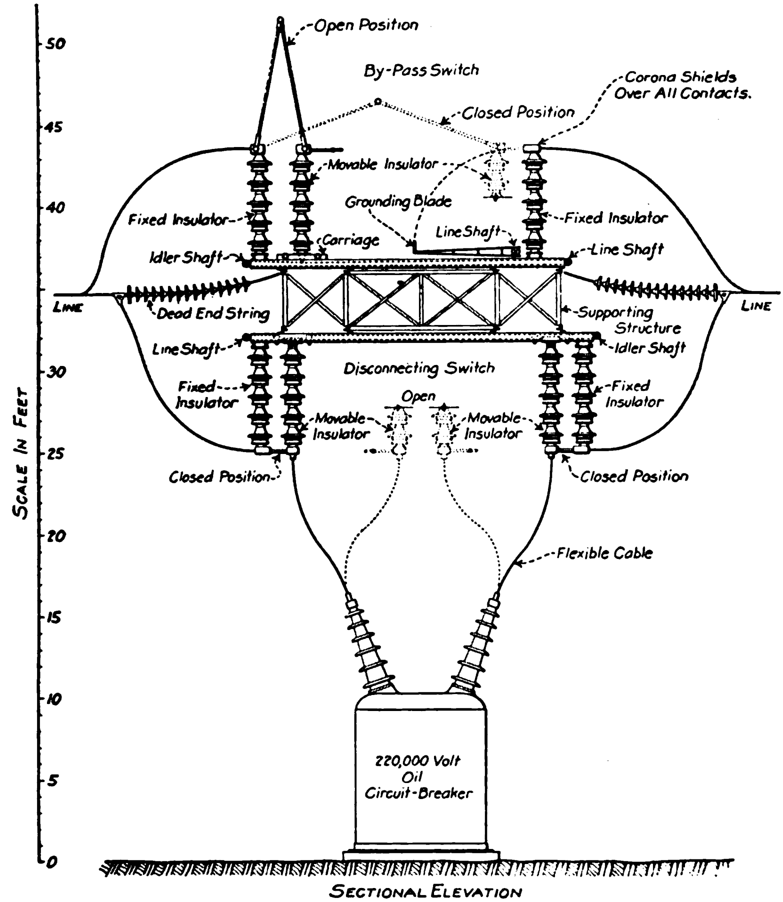
the dielectric circuit it would cause a rupture of insulation or flashover.

The most important form of solid insulators employed on 220 k.v. equipment are the bushings used to bring out the lead terminals of the transformers and oil circuit breakers. Two kinds of bushings are commonly used—the oil filled and the condenser types. In the design of oil filled bushings two problems present themselves: The internal stress on the oil which determines the puncture voltage, and the external stress on the air which determines the arc-over voltage. The condenser type bushing is built with the object of stressing all of the solid insulating material approximately equally, which may be accomplished by means of a number of cylindrical concentric condensers of equal thickness but unequal lengths.

Whereas the design of the station apparatus insulation did not present appreciable difficulties the problem of line insulation required a great deal of research and experimentation. It soon became clear that a statement of volts and number of units in a string does not determine the stress on an individual unit. The general understanding is that the stress on the insulation does not depend altogether upon the voltage but also upon the configuration or the shape of the electrodes, for example: with needle points the flux density at the point is very great at a fairly low voltage, while for large spheres a very high voltage is required to produce high flux density. Every insulator in a string may be considered as a condenser and a string can generally be thought of as consisting of a number of separate condensers in series, the dielectric being alternately air and porcelain. The fact that the ratio of the mutual capacity of the units to the capacity between the suspension link and ground is an important factor in determining the distribution of potential over an insulator string, suggested the importance not only of the shape and surface area of the metal fixtures on the individual insulators, but also the length of the connecting link or spacing between the insulators. Laboratory tests using potentiometers have shown that where the mutual capacity is small in relation to the ground capacity there soon comes a point beyond which it is useless to put more insulators in the string. The problem

therefore was to secure a more or less evenly distributed potential gradient. In order to correct this gradient and make it a uniform slope more nearly approaching the ideal straight line several methods have been employed to adjust

Fig. 6.



Sectional elevation of the Pacific Gas and Electric Company switching equipment.

the capacity. The use of insulators of varying capacity in the string was found to be a good solution but it had obvious disadvantages from a line maintenance point of view. It has nevertheless been employed on the high lines of the Pacific Gas & Electric Co.

Investigations conducted by Prof. Harris J. Ryan and his associates in the high voltage laboratory of Leland Stanford University, Cal., have shown that the distribution of potential across the insulator units becomes less uniform at higher voltages, the gradient being extremely high on the unit near the line. However it was found possible to direct and modulate the critical strains set up in the atmosphere surrounding a conductor so as to distribute the charge over a string of several insulators. This was accomplished by means of a metal shield, or ring, surrounding the lower unit, thus increasing the capacity. Prof. Ryan conducted experiments so to determine the form of the electrostatic field surrounding insulator strings as to relate the size, shape and location of the shields in a way that the stress on the live end units will be decreased, yet not unreasonably decrease the flashover distance to tower and crossarms. Reducing the high voltage across the line unit, he eliminated local corona discharge at this point and, moreover, encouraged the flash-over to pass from the shield ring to ground, the arc not being destructive to the insulators.

Regarding the application of shield rings, opinions among operating engineers are still divided. On all the early installations shield rings, or discs, were installed along the lines and on the disconnecting switches in the substation. The present tendency is so to design the conducting parts and hardware as to avoid the necessity for using shields.

The use of the shield ring has done much to show that certain external modifications may radically alter the duties and efficacy of insulators. A metal shield carefully shaped and connected to one end of an insulator unit provides an equipotential surface which distributes the field. Some of the European manufacturers recognizing the value of the metal shield have developed a new type of insulator made of a cylindrical porcelain body, with only one shed to minimize leakage, and a metal cap cemented at each end, the one at the top being provided with a wide copper shield. A step further in this direction was taken by Prof. Harold B. Smith, of the Worcester Polytechnic Institute. His design not only provides for proper distribution but furthermore places the actual dielectric in the zone of min'mum density. Electrical

breakdown therefore occurs not in the insulating element but somewhere in the surrounding field, thus the heating and ionization of the dielectric, which are generally supposed to precede the breakdown, are obviated. The effect'veness of this insulator was demonstrated at the A. I. E. E. Convention held in Pasadena, in 1924, at the inauguration of the new 1,000,000 volt laboratory of the California Institute of Technology. It took almost 1,000,000 volts to arc over two of the insulators in series.

In reviewing the problem of 220 k.v. development, consideration so far has been given to the design of equipment and apparatus. Now it remains to consider the operation of the existing systems. The experience of commercial application of 220 k.v. dates from the latter part of 1923, and, notwithstanding its imperfections, the system has given comparatively little trouble. The greatest difficulty outside of purely incidental cases is caused by faulty relay operation and the flashovers, the latter presenting the greatest source of trouble and frequently perplexing the operating engineers. There is still the necessity of exercising great vigilance and careful investigation of lines while operating under conditions of heavy switching and during atmospheric discharges. In the early stage of the development it was assumed that the line should be designed so as to operate at nearly critical corona voltage, any disturbance, therefore, resulting in a higher voltage would quickly expend its energy in producing corona loss. This in turn would permit a smaller safety factor to be used on the insulation.

A detailed investigation of corona loss was made by Peek and expressed in his well-known quadratic law. Accurate power measurements of corona loss on a high tension line are difficult to make because of the nature of the phenomena and the circuit itself. Measurements on the low side of transformation could not be relied upon due to the difficulty of separating the different losses. Recent measurements with cathode-ray oscillograph have shown that the loss follows the quadratic law only above the visual critical voltage. Peek's formula, therefore, was found to be close enough for established corona conditions, whereas in actual practice on high voltage lines under normal atmospheric conditions the con-

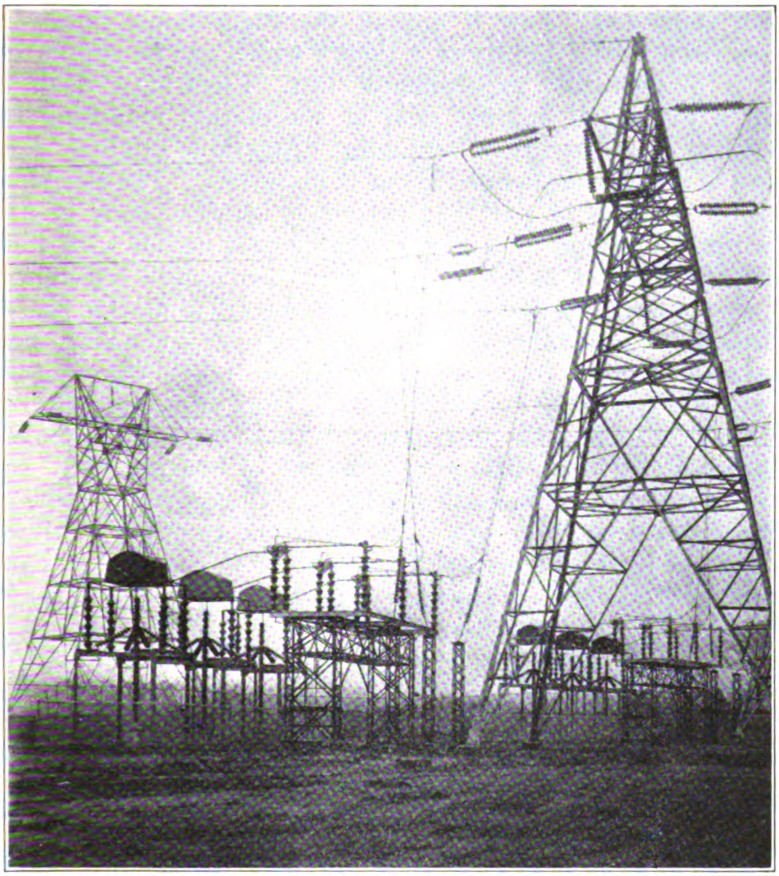
ductors show no visible corona, and when the nature of the phenomenon becomes unstable the loss is extremely difficult for exact calculation. It appears that the most dependable method of accounting for corona losses would have to be based upon actual measurements on the high voltage side.

Considering the possible future development of a national interconnection it may be worth while to mention the possibility of 220 k.v. underground transmission. It is well understood that overhead circuits are exposed to a great extent to the influence of the weather, particularly storms and rain. There always adheres the disadvantage of an open air circuit being subject to all influences including intentional malicious interference. Another drawback is the impossibility of bringing the overhead 220 k.v. lines directly into the city. For these reasons the future development of 220 k.v. interconnection may be in the direction of underground cables. An important factor to such decision may be eventually the rapid development of aviation, to which high voltage lines represent great danger, and there will be hardly any means in the event of sudden fog to render the existence of overhead lines noticeable to the flyer. At the same time it is well understood that maintenance of cable network and supervising service is much smaller than with an exposed overhead line, the life of the cable being correspondingly longer.

The insulation of high voltage cables is always of limited thickness and therefore subject to a high dielectric stress. Dielectric losses are known to cause internal heat which raises the temperature. This in turn limits the current capacity and produces local heat spots and deterioration of the dielectric material leading ultimately to failure. At present, efforts are being made to deal in a scientific manner with the subject in which the past development has been so far largely experimental and "cut and try methods." The general problem of insulation is emphatically one in which scientific treatment is to be sought for. At the same time it is necessary to urge the utmost caution in interpreting the dictates of new theories. Care needs to be exercised not only in connection with the more complicated problems of insulation but danger exists in making errors in the interpretation of the fundamental laws which effect the result in the most simple cases.

Even the simplest natural phenomena leave us groping when we seek their ultimate understanding as a sequence of cause and effect. In our effort to understand the nature of each cause we soon reach the limit of our exact knowledge and

Fig. 7.



Plymouth Meeting. General view of 22003–22010 kv Westinghouse lightning arresters.

are led into the realm of metaphysical speculation. For the most part, in the field of dielectric phenomena, we would be content if we could express them in terms of the fundamental relations of mass, motion and energy which are the foundation stones for erecting the structures of theories accounting for

more complex natural phenomena. The word theory is therefore only a relative term, meaning that we can explain a newly observed phenomenon in terms of a more fundamental phenomenon whose laws are well recognized. Since the earliest discovery of the property of dielectrics many hypotheses and explanations of their origin and nature have been suggested. Few if any of the suggestions, however, have risen to the dignity of a theory which can be supported by a quantitative experimental test. Electricity itself is still a matter of a great deal of speculation regarding its meaning and nature. Benjamin Franklin's original conception of it is thus defined in one of his letters, "The electrical matter consists of particles extremely subtle, since it can permeate common matter even the densest metals with such ease and freedom as not to receive any perceptible resistance. If any one should doubt whether the electrical matter passes through the substance of bodies or only over and along their surfaces a shock from an electrified jar taken through his body will probably convince him." How admirably simple and, at the same time, instructive to those engaged in studies pertaining to the ultimate structure of matter with the powerful aid of mathematical science. Of course the modern transmission engineer would be ess prone to apply methods suggested by Franklin, when attempting to convince anyone about the existence of electricity, because the mere approach to a 220 k.v. transmission line at any distance less than four feet is positively sufficient to relieve any living creature of all his earthly cares.

Benjamin Franklin was the first to show the importance of the dielectric medium when he described the properties of a Leyden jar. Faraday's great contributions to the study of dielectric properties of material were his ideas of lines of force, tubes of induction, dielectric polarization his emphasis of the importance of the medium in the phenomenon of electrostatic induction, his measurements on different dielectrics, and his discovery of the fundamental property, spec fic inductive capacity. But it was the genius of Maxwell that built the theory of potential as applied to the electric field and to dielectric behavior, which still constitutes the starting point of any discussion of dielectric phenomena. Yet the

classical theory developed by Faraday and Maxwell assumes that dielectrics have only one property—the specific inductive capacity. It tells us nothing of dielectric strength, of phase difference under alternating stress, and very little of the conductivity of dielectrics. While the relative importance of these properties may vary as amongst different types of service, all of them are involved in high voltage alternating current service. The classical theory is utterly insufficient to guide us in our efforts to understand and control the important properties of insulation as utilized in high voltage equipment. Extensive research conducted during the last twenty-five years was instrumental in the discovery of certain properties not accounted for in the theory of perfect dielectrics. It was soon recognized that these special properties are perhaps the most important of all, owing to the limitations they impose on the performance of high voltage insulation. The most important of these properties are the dielectric absorption and the dielectric loss.

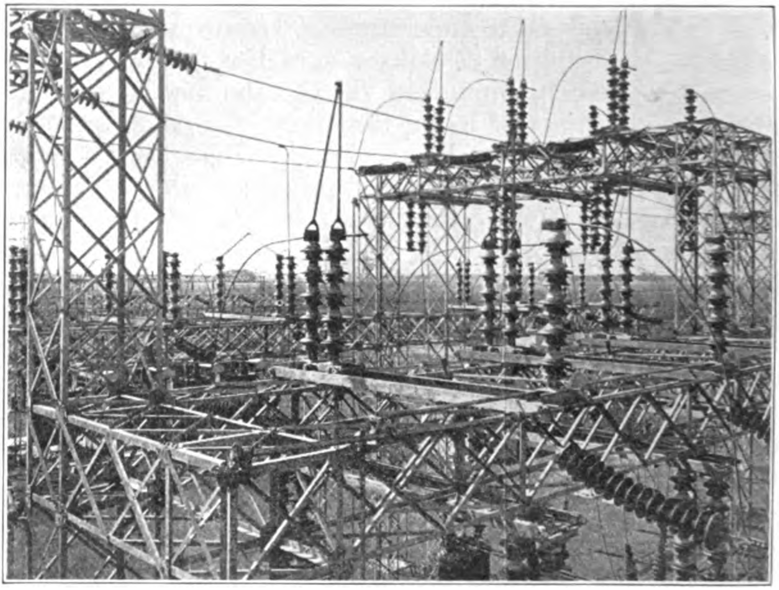
From the standpoint of engineering practice the dielectric absorption is considered as a conduction phenomenon and therefore, in all cases of alternating stress, occasions a component of current in phase with the applied voltage. This means an energy loss in the dielectric, causing heating and danger to the insulation. The situation is aggravated by the fact that in high voltage equipment composite insulation is used which usually possesses high absorption. The fundamental loss of even the purest and simplest of dielectrics is not clearly defined. While the explanation of dielectric loss is obvious, it is not yet possible to formulate definite laws connecting the losses in dielectrics with the simpler and more fundamental properties of the materials themselves.

Of all existing theories which propose to account for these special properties no single one of them is entirely satisfactory. Many of them are obviously imaginary structures erected in the effort to picture some artificial mechanism conforming to the known experimental facts. Others are merely ingenious sequences of mathematical manipulations.

CONCLUSIONS.

Summarizing the entire field of 220 k.v. development and its present status certain general conclusions may be drawn. It is evident that the development leaves much room for improvement in general methods, apparatus and installation. The critical eye is impressed when observing the mass of steel,

Fig. 8.



Typical arrangement of the Pacific Gas and Electric Company.

copper, oil and particularly the porcelain and hardware of the insulation used to commutate electric current, that there is something wrong with the present way of attacking the problem. What may be termed "brute force" characterizes the proportioning and methods of using the material. There seems to prevail a strong adherence to the old practice while neglecting the quest for new ways. Many things have been actually applied where far greater care should have been exercised in their choice. Nevertheless we often hear undue praises which call for sounding the alarm of caution. Perhaps it might be worth while to quote the concluding paragraph of Franklin's letter to an English scientist in which, after a long

description and explanation of strikingly original new experiments with electricity, he writes, "These thoughts, my dear friend, are many of them crude and hasty, and if I were merely ambitious of acquiring some reputation in philosophy I ought to keep them by me till corrected and improved by time and further experience." This thought occurred to me when looking at the first steps of our practical application of 220 k.v. equipment. A study of these first installations would prove of great interest and value to every power engineer, for by intelligent analysis he could learn at least one important thing and that is—how not to design 220 k.v. equipment.

The problem of insulation should perhaps be approached from a new angle. It can no longer be viewed as one of interposing a certain thickness of insulation or a greater number of cap and pin units between the line and ground. A thorough knowledge and understanding of the material used and its properties is of the greatest importance. The engineer, therefore, can no longer content himself with the former rules of engineering practice, for the equipment and devices which he has come to use draw more and more upon the properties of fundamental and fine grained structure of nature, the elucidation of which is the problem of modern science. In the meantime, however, it is necessary to use available equipment and to improve the methods of use rather than to await developments which may some day offer the solution devoutly desired. Further experimental and theoretical research is of vital importance to lessen the confusion and uncertainty of our new power developments, and it would be wise to recall what Franklin said of research, "Frequently in a variety of experiments though we miss what we expected to find yet something valuable turns out, something surprising and instructing, though unthought of." That something can be expected only when research keeps in step with actual field and operating experience, and every inducement should be offered to open minded engineers for developing a greater theoretical knowledge of the art.

Evidence of the Presence of Protons in Metals. ALFRED COEHN. (*Naturwissenschaften*, March 16, 1928.) A quantitative study of the solution of hydrogen in palladium, iron and other metals indicates that it exists there in atomic form. If this be the case, it would seem likely that some of the hydrogen atoms would liberate electrons as the metal atoms are supposed to do. In the metal there should then be electrons derived from both hydrogen and metal atoms, neutral metal atoms, metal atoms rendered positive by the loss of negative electrons, neutral hydrogen atoms and protons, that is, positively charged hydrogen nuclei resulting from the removal of the electron from a hydrogen atom. The atoms of metal are fixed in position on the crystal framework but the hydrogen can move and does move as is shown by experiments on its diffusion through metal foil.

Protons have a positive charge. Can their motion in metals be affected by the application of an electric field? To answer this the following experiment was tried. The middle centimeter of a palladium wire 6 cm. long was twisted together. This part of the wire dipped into dilute sulphuric acid, extended vertically upward and was prolonged horizontally to right and left by the remainder of the wire. Each horizontal part of the wire had V-shaped bends in it for testing potential by contact with dilute acid. By making the twisted part the cathode hydrogen was supplied to it. This diffuses impartially toward both ends of the wire. Let the wire now be traversed by a second current, independent of the electrolyzing current and much stronger than it. Under these conditions the hydrogen travelled faster toward the cathode end of the wire. Its presence was detected by the difference of potential set up. After the second current had flowed for 55 or 60 hours two corresponding places to right and left of the twisted wire showed a difference of potential of .1 to .15 volt. Reversing the current caused a reversal of the potential difference between the two points. It was thus possible to drive the hydrogen back and forth in the palladium wire. The conclusion is that protons are present in the wire. G. F. S.

COMMITTEE ON SCIENCE AND THE ARTS.

ABSTRACTS OF REPORTS.

SPELLER'S METHOD OF MAKING AND FINISHING WELDED PIPE.

HALL OF THE INSTITUTE,
PHILADELPHIA, November 2, 1927.

No. 2873.

THE Franklin Institute of the State of Pennsylvania, acting through its Committee on Science and the Arts, investigating Doctor Frank N. Speller's Method of Making and Finishing Welded Pipe, reports as follows:

The purpose of this invention is the mechanical removal of the thick oxide scale that is found on the surface of pipes that are made by the welding process. The removal of this scale cleans the surfaces of the pipes, making it possible to apply a more uniform coating of zinc, or other protective materials, for the prevention of corrosion.

The invention is protected by a number of United States patents, the earliest application having been filed on February 8, 1913, for a "Method of Finishing Welded Pipes," on which patent Number 1,171,757 was granted on February 15, 1916, to Frank N. Speller, of Pittsburgh, Pennsylvania.

The method of removing scale in the prior art was by the use of an acid pickling bath. The objection to this method is that since the thickness of scale on the inside of the pipe varies and averages greater than that on the outside, either patches of scale are left on the inside or the outside is over pickled, or burned.

In the process under investigation the scale is removed while the pipe is at a forging heat, but at such a temperature that while passing through the rolls, the scale will crack and separate from the metal.

A flat piece of skelp from which pipe is to be made, is heated in a welding furnace. Leaving the furnace, it goes onto a draw bench on which it is welded into a pipe by the butt weld process. It then is passed through sets of rolls

by which it is reduced in diameter and made truly cylindrical while its temperature is slightly below that of welding. The pipes are then carried sidewise across a transfer table at such a rate that they cool to a temperature slightly below that at which the scale sets. On leaving this table they are passed lengthwise through sets of rolls by which they are first changed in cross section to an oval shape and then back again into a circle. In this process the mean diameter is reduced and the length increased.

In this operation the scale on both the outside and inside is cracked off and removed while the temperature of the pipes is sufficiently high to prevent injury to the metal.

This process has been in extensive use since 1913 by the National Tube Company and for a shorter time by other companies. This pipe is in use as conduit for electric wires. and has been investigated and approved by the Underwriters for that purpose. It is also extensively used for water, gas and steam conduits.

The smooth interior of welded pipes that are scale free. provides a channel for water, that has little friction and secures a full delivery since there is no obstruction to the flow. The difficulty of clogged valves due to loose scale does not occur with a scale free pipe and there is much less pitting of the pipe.

The thick scale left in the inside of pipes by the ordinary methods of manufacture is the cause of most of this pitting which is the result of an electrolytic process since the scale is negative to the metal and under certain conditions a thermo-electric couple is set up. The removal of the scale prevents such action and leaves a smooth uniform interior surface.

Seven claims are allowed in Patent No. 1,171, 757. The first refers to the method of finishing welded pipes which consists in altering the cross sectional contour of the welded pipe while heated to a temperature at which the scale sets.

Claim seven describes the method in detail as follows:

> "The method of finishing welded pipes which consists in welding the pipe skelp, cooling the welded pipe to a temperature below that at which the scale sets, and then distorting and restoring the cross sectional contour of the pipe to thereby loosen

and remove scale from the surfaces of the pipe and elongating the pipe in the distorting and restoring operations."

Replies received to letters of inquiry to users have been very favorable concerning the practical use of this pipe.

In consideration of his invention of a method of manufacturing scale free pipe and its successful application, THE FRANKLIN INSTITUTE awards its EDWARD LONGSTRETH MEDAL to DOCTOR FRANK N. SPELLER, of Pittsburgh, Pennsylvania.

THE WORK OF HENRY FORD.

HALL OF THE INSTITUTE,
PHILADELPHIA, March 7, 1928.

No. 2878.

The Franklin Institute of the State of Pennsylvania acting through its Committee on Science and the Arts, investigating the Work of Henry Ford, of Detroit, Michigan, reports as follows:

Henry Ford, the son of William and May Litogot Ford, was born on July 30, 1863, at Greenfield, near Detroit, Michigan. His early life was spent on his father's farm and his education was received at the district school in Greenfield. Living the life of a farmer's boy he became acquainted, in a practical way, with the work to be done on a farm, and later used this knowledge to good advantage in devising machines that have proved of great value in farming operations.

The long and toilsome days of the busy season on the farm did not appeal favorably to young Ford, and since he was interested in all kinds of machinery, he became an apprentice in an engine works where he learned the machinist's trade. Becoming an expert machinist he made rapid progress, and was advanced from one position to another until he became the chief engineer of the Detroit Edison Company.

Mr. Ford made many inventions, and took out many letters patent, in foreign countries as well as in the United States. The first in the United States, No. 686,046, was issued on November 5, 1901, for a Motor Carriage, and was assigned to the Detroit Automobile Company. Many patents

followed in later years, covering many parts of an automobile, and accessories, such as mufflers, chain adjustments, drive gears, steering mechanisms and speed controllers. Perhaps of all Mr. Ford's inventions, that of the planetary drive gear (U. S. Patent No. 787,908, of April 25, 1905) was most significant; for that gear was used on the famous Ford car known as the Model T. These patents of course covered the four cylinder car, known as Model N, of which there were sold in two years a number of cars in excess of the total number of automobiles which all the motor car makers of the world together had been able to produce previously.

The first car was completed in 1892 when Mr. Ford was twenty-nine, but the increase in production was slow for the first few years, it being ten years before the first thousand machines were built. The Ford Motor Company was formed, though, with a small amount of paid in capital, about $28,000, and its progress was necessarily slow. During the early years of automobile production, development was delayed in many cases on account of the Selden patents which were so broad that they covered almost any kind of motor applied to a four wheeled vehicle. Manufacturers were compelled to pay royalties on this patent for some years until after a long series of legal trials the matter was finally settled by a decision in the United States Court of Appeals, in the case of Selden vs. Ford, et al., which declared that the statement "that Selden has solved a great problem and is entitled to the status of a pioneer inventor, is, we think, without foundation."

In all of this litigation Mr. Ford was a leading figure.

In the meantime automobiles were being built abroad by Daimler and Bentz, and in this country by Duryea, Ford, Olds and others and the defeat of the claims of the Selden patent gave such an impetus to automobile construction that the number in use rapidly increased.

The manufacture of machine Model "N" was discontinued and the Ford Machine, Model "T," was standardized in 1908, both as to type of machine and method of manufacture. The output of the Ford automobile manufactory increased from about 10,000 in 1908 to 2,000,000 in 1923 with a falling off during the years of the World War.

The reduction in cost of the Ford car to less than one-

third of the original cost is due to a combination of the following causes: the making of a standard car with parts that are interchangeable; standardization of the manufacture of it; the introduction of moving conveyers by which the work is brought to the workman, each man doing one operation at which he becomes expert, and a determination on the part of Mr. Ford to furnish these cars at prices low enough to permit of their widespread use.

The conveyer system employed in the Ford plants has been an important factor in securing a high rate of production. In this system a continuously moving platform is loaded at the proper intervals with the parts to be used by the workman who stands in one place and makes use of the part as it is brought to him. A careful test is made of the time of each operation and the rate of the moving conveyer regulated accordingly.

The practical result of the introduction of this system has been to increase greatly the speed of manufacture and to facilitate mass production. The last operation in the succession is the assembling of the automobile, which is done on a long moving platform or track, on which the different parts are added in order. When the end of the track is reached, the car can be driven off under its own power.

The conveyer system applied to the assembling of cars, introduced by the Ford Motor Company, and which has been revolutionary in its effect, is now in general use by the automobile and other industries where mass production is required.

On May 26, 1927, the 15,000,000th Ford automobile left the platform driven by Edsel Ford, President of the Company, with his father as passenger. Going to the Museum of the Company, Ford Machine No. 1 was brought out and driven by Henry Ford.

The tremendous increase in the output of the Ford Motor Company is seen in the fact that it operates thirty-five branches in the United States of which thirty-two are assembly plants.

The increased manufacture called for a great amount of raw material and for its preliminary manufacture into the various parts used in an automobile. Believing that these

parts could be manufactured for a lower price by his own plants than that paid for them in the markets, Henry Ford undertook the purchase of raw material and its manufacture as required. This included the acquisition of iron and coal mines and timber lands, and the building of a railroad and line of steamboats. Raw materials are conveyed to the River Rouge plant, which is provided with coke ovens, blast furnaces and saw mills. This plant is equipped with electric furnaces, a cement plant, a glass factory, paper mill, foundry, and machine shops. All these being under the control of a single organization, are highly efficient in producing an economical manufacture of the Ford automobile.

In order to carry out his idea of making machines suitable for farm work, Mr. Ford took up the production of small tractors at the River Rouge plant where the factory for building them has a capacity of 750 "Fordsons," as these tractors are called, each day. These tractors are adapted to many kinds of work and have largely replaced horses.

The extended use of the Ford automobile has resulted from the ability of the company to produce a reliable small car at a low cost. This has been accomplished through Mr. Ford's originality in manufacturing methods, and his genius in building up a large organization, with the economies in buying, manufacture and distribution possible only in large scale operations.

The inexpensive Ford car and truck have materially changed conditions on the farm, enabling a farmer to command better and diversified markets, and to enlarge the social and intellectual contacts of himself and family. The Fordson tractor has increased his efficiency as an agriculturist, and particularly in the Northern States, by dispensing with horses, has enabled him to devote a greater area to crops not consumed on the farm.

To the workman, speedy transportation has opened up a larger field of operation. To the average citizen, the inexpensive car has developed many sources of pleasure heretofore enjoyed only by the wealthy few; and by making possible a more extensive and diversified travel, has created a better knowledge of our country and developed a broader vision.

In consideration of his rare inventive ability and power of

organization, by means of which he was able to effect high speed production of automobiles, revolutionizing the industry; and his outstanding executive powers and industrial leadership, THE FRANKLIN INSTITUTE awards its ELLIOTT CRESSON MEDAL to MR. HENRY FORD, of Detroit, Michigan.

WRIGHT "WHIRLWIND" ENGINE.

HALL OF THE INSTITUTE,
PHILADELPHIA, March 7, 1928.

No. 2890.

THE Franklin Institute of the State of Pennsylvania, acting through its Committee on Science and the Arts, investigating the Wright "Whirlwind" Engine developed by Mr. Charles L. Lawrance, of Long Island, New York, now President and Chief Engineer of the Wright Aëronautical Corporation, of Paterson, New Jersey, reports as follows:

History: At the close of the World War the American aircraft engine industry was concentrated on water cooled engines. This was logical as the water cooled engines had been more successful than the early air cooled type and none of the latter had been developed in the higher powers.

In 1916 Mr. Charles L. Lawrance begun a development of air cooled engines of small power for airplane service in an endeavor to eliminate defects known to exist in previous types of rotary air cooled engines, such as gyroscopic effects, oiling trouble and improper gas distribution, and shortly after produced the three cylinder Lawrance L2 radial air cooled engine. This engine made some notable flights in small planes, but was superseded in a short time by the Wright "Gale" L4 Engine. This was also a three cylinder radial engine and developed 60 horsepower at 1800 r.p.m. It had a bore of 4.25″ and stroke of 5.25″ and weighed 140 pounds.

The success of these low power air cooled engines led to the securing of development contracts from the U. S. Government in 1920 and 1921 for nine cylinder radial air cooled engines of 140 and 200 horsepower. These two engines were developed simultaneously and both passed their fifty

hour acceptance tests in 1921. This second engine was the forerunner of the now famous Wright "Whirlwind" which we have under consideration. It has passed through seven successive models without changing the basic design or bore and stroke.

Following the success of the "Whirlwind" engine, engines of other makes and similar construction are now being produced and are in use.

Patents: Since the Wright "Whirlwind" Engine is the result of a continuous development extending over a period of years, the patents that have been granted on it are rather for modifications and improvements than for the engine as a whole. These patents have been granted to different persons but two of the important ones were issued to Charles L. Lawrance who designed the air cooled engine developed into the present type.

United States Patent No. 1,338,310 for which the application was filed September 6, 1918 was granted to Mr. Lawrance on April 17, 1920. This patent was for a lubricating system for high speed engines and the invention was for the purpose of avoiding the trouble previously caused by the heating of the crank pin. This invention avoids the trouble by using a hollow crank and crank pin forcing oil through them at high speed to conduct away the excess heat.

Five claims are allowed in this patent of which the third is as follows:

> "The combination in a high speed engine having a crank case, of a hollow crank, and bearings which receive oil through the interior of the crank and discharge lubricating oil into said case, a pump connected to deliver oil to the interior of said crank shaft and adjusted to deliver an excess of cooling oil above that required for lubricating the bearings supplied through said crank shaft, and a cooler connected to receive said excess oil from said crank shaft."

Another invention by Mr. Lawrance is for the "Big-End Construction for Radial Motors," and patent No. 1,398,194 was granted for this invention on November 22, 1921. Mr. Lawrance describes the purpose of the invention as follows:

> "My present invention relates to radial motors and particularly to that type in which a plurality of connecting rods are connected to a master piston rod about its bearing on a common crank pin.
>
> "The articulation of these several auxiliary connecting rods on the crank pin bearing of the master rod involves a variety of structural difficulties which had been only partially met and it was the object of my present invention to so improve this rather frequently used system of radial connecting rod assembly as to give a maximum of freedom to each rod with great strength and lightness."

The fourth of the seven claims allowed in this patent reads as follows:

> "In a motor of the class described, a crank assembly comprising a bearing sleeve on the crank pin and carried by one of the master rods, and a plurality of auxiliary connecting rods spaced about said bearing and connected thereto each by a joint consisting of a pair of longitudinally disposed end bearings, a central bearing rib, and a pin passing through said end bearings and the interposed end of a connecting rod, said connecting rod being slotted to permit the central bearing rib to contact with the lower face of the hollow pin."

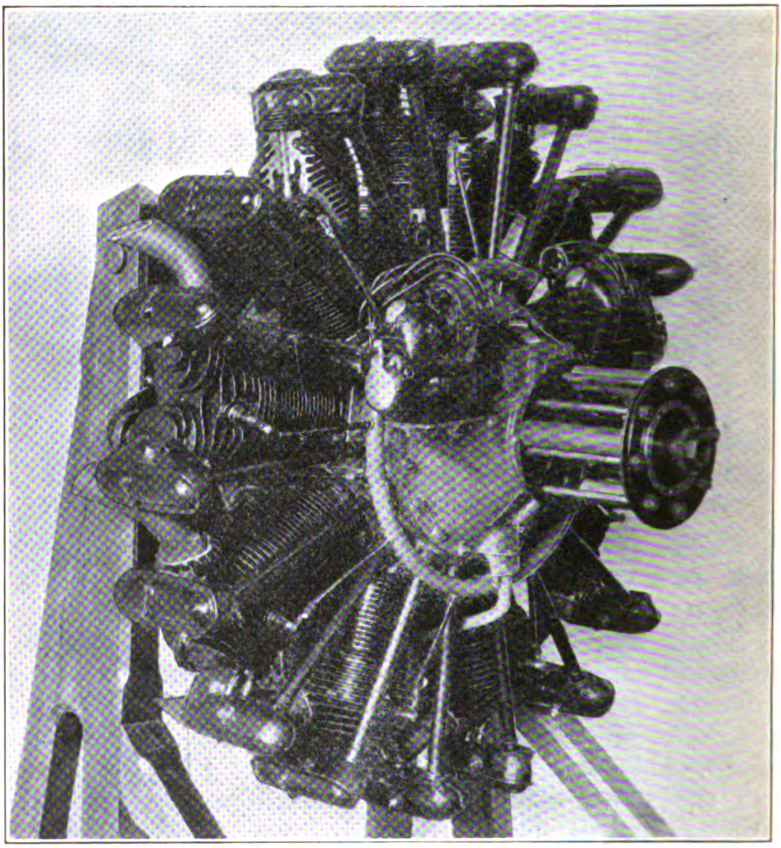
Design and Construction of the J5 Model: Figure 1 shows a front view of this model with propeller hub cap; Figure 2 shows a rear view.

The most efficient air cooling of an aviation engine is accomplished by causing air from the propeller slipstream to strike the cylinders laterally at right angles to the cylinder axis. This requires circumferential finning. The "Whirlwind" engine has aluminum alloy heads with cast fins to cool the valve seats and the combustion chamber. The cylinders proper are of steel with fins turned from solid forgings. They are screwed and shrunk into head castings using castor oil and graphite to lubricate and seal the threaded joint. The reason for radial cylinder design is due to the fact that more uniform cooling can be secured for each cylinder without necessity of an air distributing device.

The selection of an odd number of cylinders is due to

the use of the familiar four stroke-cycle of operation. If an even number of cylinders were used on a radial engine it would be necessary to fire them in pairs or else fire them successively during one revolution and skip the next, with consequent uneven impulse on the propeller.

FIG. 1.

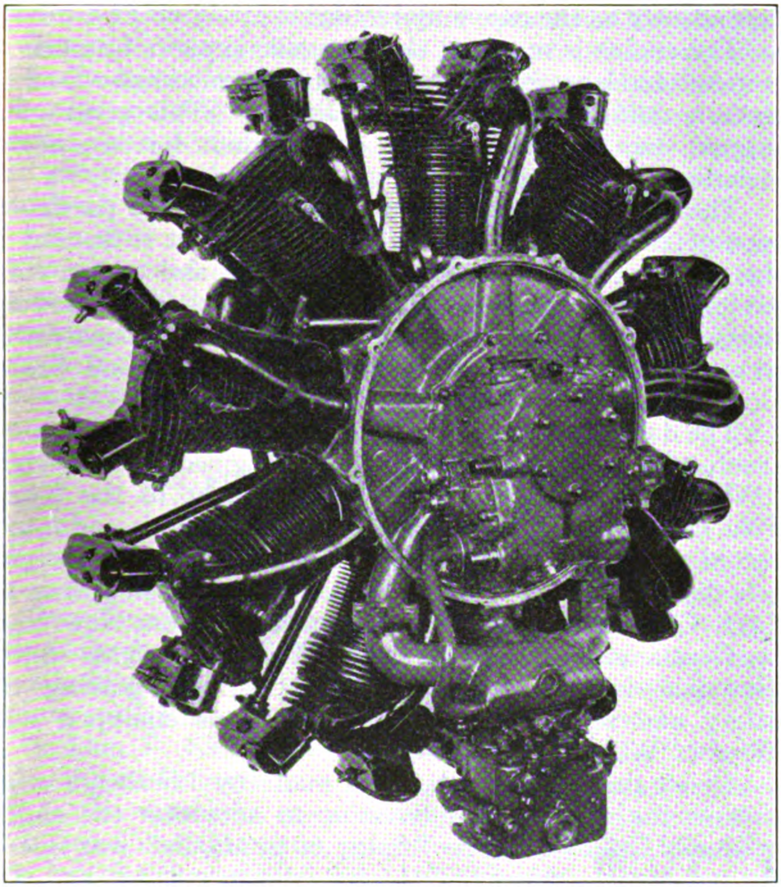


With an odd number, the firing order progresses around the cylinders skipping every other one so that the impulses on the propeller are uniform and all the cylinders are fired in two revolutions. Nine cylinders were selected for the "Whirlwind" engine so as to secure a 200 h.p. engine using

cylinders of size and design developed for the original Lawrance engine.

The mechanical balance of a radial engine involves the use of counterweights and takes into account the entire

FIG. 2.



weight of rods and pistons. The center of gravity of this system travels approximately in a circle if the stroke is reasonably short.

The design of the master rod involves an interesting study of knuckle pin travel so as to maintain an equal compression ratio in the cylinders.

Gas distribution is naturally an important consideration and is accomplished by three manifolds, each serving three cylinders. A single three barrel carburetor is used connected to the three manifolds.

Two separate sets of spark plugs are used and two high tension magnetos are provided working together or independently as the case may require.

The engine is mounted on a metallic support fastened to a metal fuselage structure now almost universally used in modern military or commercial aircraft. This gives ideal support for the engine with ample room for accessories including starter, etc.

The use of this engine is not confined to any particular type of airplane as is shown by the fact that it is used in the planes of ten mail carrying companies and twelve companies using planes for business purposes. It is used by thirty companies in passenger and other air transportation service—also in seven departments of the United States Government and seven foreign governments.

The daily press has made everyone familiar with the more spectacular performances of planes engined with Wright "Whirlwinds." These include Byrd's flight to the North Pole on May 9, 1926, Chamberlin and Acosta's endurance record of fifty-one hours, starting April 12, 1927, Lindbergh's solo flight from New York to Paris, France, starting May 20, 1927, Chamberlin's flight with a passenger from New York to Germany, a few days later, Maitland's flight to the Hawaiian Islands and many other records, proving the safety and reliability of modern airplanes equipped with Wright "Whirlwind" engines.

Of all these flights, the ones made by Lindbergh overshadow the rest. It is interesting to note that the engine originally installed in the "Spirit of St. Louis" was one of the ten special engines built for long distance flights and that it was still functioning satisfactorily when he landed in St. Louis on his return from his trip through the Southern Republics.

These engines were special only in the methods of inspection used and were so successful that all stock engines are now identical in material, inspection and workmanship with Colonel Lindbergh's engine.

It seems fitting that The Franklin Institute should recognize the vision, engineering skill and executive ability of Mr. Lawrance in pioneering the air cooled airplane engine and developing it to its present successful form. Included in this task was the development of new materials and facilities for building this remarkable mechanism and its testing. A trip through the shops of the Wright Aëronautical Corporation at Paterson, New Jersey, reveals the most precise machine work, the most painstaking care in inspection and assembly—elaborate proving apparatus is provided including wind tunnels, electrical dynamometers and all necessary meters and gauges, so that when an engine leaves their works, a Lindbergh may use it to arrest the attention of the world.

In consideration of his pioneer work in the development of the air cooled airplane engine, of his skill in bringing this engine to a high degree of perfection and of his ability in carrying out its manufacture, THE FRANKLIN INSTITUTE awards its ELLIOTT CRESSON MEDAL to MR. CHARLES L. LAWRANCE, of Long Island, New York.

THE WORK OF WILLIAM F. KIESEL, Jr.

HALL OF THE INSTITUTE,
PHILADELPHIA, April 4, 1928.

No. 2892.

THE Franklin Institute of the State of Pennsylvania, acting through its Committee on Science and the Arts, investigating the Work of Mr. William F. Kiesel, Jr., of Altoona, in Railway Engineering, reports as follows:

William F. Kiesel, Jr., was born on September 1, 1866, at Scranton, Pennsylvania, and after serving an apprenticeship in the machinist trade in the shop of the Lackawanna Iron and Coal Company, prepared for Lehigh University from which he was graduated in 1887 with the degree of Mechanical Engineer. After graduation he spent a year in the service of the Lehigh Valley Railroad and of the Lackawanna Iron and Steel Company. He entered the office of the Mechanical Engineer of the Pennsylvania Railroad at Altoona, Pennsylvania, as draftsman, April 9, 1888. After a service of several years in this position he was appointed Chief

Draftsman on March 1, 1899; Assistant Engineer on July 1, 1900; Assistant Mechanical Engineer on September 1, 1902 and Mechanical Engineer on February 1, 1919, a position which he now holds.

One of the first things to which he gave his special attention was an improvement in the kind of water scoop used on locomotive tenders for taking water from the troughs while the train was running. The scoop then in use did not operate properly at high speeds. To overcome this difficulty Mr. Kiesel devised a balanced water scoop which was mounted on trunnions in such a way that it removed the difficulty and could be operated with ease. This device is described in U. S. Patent No. 531,191 issued to Mr. Kiesel on December 18, 1894, and is now the one in use on the Pennsylvania Railroad.

Mr. Kiesel next took up work on the compound locomotive and prepared designs covering several systems of compounding as applied to the Mogul locomotives (Class F2).

With the advent of the all steel passenger car, more powerful locomotives than those of the Atlantic type, then in general use, were required and Mr. Kiesel's work resulted in the design of the E6s type, more than eighty of which were built in 1912. These locomotives gave excellent results on the main line for a number of years but have now been generally replaced by still more powerful locomotives.

The trailer trucks used with this type of locomotive not having given satisfaction, Mr. Kiesel designed a form having outside journal bearings and with the truck frame so arranged that it served as an equalizer between the driving and trailer axles. This design of trailer truck proved to be so superior to previous ones that it is used with all locomotives of the Pennsylvania Railroad on which trailer trucks are used as well as on many locomotives for other railroads. United States Patent No. 929,768 issued on August 3, 1909, describes this truck.

Mr. Kiesel's next work in steam locomotive development was the design of the K4s (4–6–2) for passenger service and of the L1s (2–8–2) for freight service. The K4s is still the standard passenger locomotive for high speed main line work but the L1s has been superseded by other types.

In order to secure the use of steam expansively and economically in locomotives used for heavy service at a low speed, Mr. Kiesel developed a limited cut-off arrangement in which the locomotive was arranged to develop its maximum draw bar pull at 50 per cent. or a little greater cut-off. To insure starting, a small port was placed in each piston valve bushing; these ports were never closed and admitted steam to move the locomotive off a dead center. This arrangement is covered by United States Patent No. 1,307,821 issued on June 24, 1919.

The most successful high speed freight locomotive ever used on the Pennsylvania Railroad is the Mi (4–8–2) type. Mr. Kiesel was largely responsible for its design and in 1926 two hundred of this type were built.

While the work of Mr. Kiesel has been of a practical nature it has been largely original and his experience has enabled him to derive empirical rules and theoretical formulæ of high value. Some of these on tractive power and train resistance have been used in Professor W. R. Wood's book on "Locomotive Operation and Train Control."

The introduction of the electric locomotive has brought about new problems of design, many of them of a mechanical nature. Among such locomotives may be mentioned those used in the Hudson River tubes to New York City, which have been in successful use since 1910, and the electric locomotives used in the suburban train service from New York and from Philadelphia. Mr. Kiesel has been largely responsible for the mechanical parts of these, and especially for the oil pump used to lubricate them. The peripheral speed of the armature journal and the necessity of keeping the excess oil out of the motor windings have required the consideration of new problems which Mr. Kiesel has been largely responsible for solving. These pumps which are now applied to all L5 type electric locomotives are six cylinder, constant pressure and keep up a circulation of filtered oil through the bearings.

One thing that has added greatly to the safety of passenger travel and the security of goods in transportation is the development of the steel car. Mr. Kiesel became interested in this improvement for freight cars in 1897 and he has been

busied in their improvement ever since. The first all steel passenger coach to be used on a steam railway was put in service in 1906 and the replacement of wooden cars by steel cars is now practically completed—the present development being in the line of refinement of design.

Mr. Kiesel's many years of service in the mechanical side of railway engineering has brought him in contact with the details of much of the apparatus that is used in a practical way and for many of the improvements that he has made United States Patents have been granted to him. This list includes about a hundred different patents granted for inventions or improvements.

While a member of the A. S. M. E. Boiler Code Committee from 1916 to 1924 he was recognized as one of the outstanding leaders in the development and formation of Boiler Codes for Power, Heating and Locomotives. Many of the formulæ applicable only to locomotive boilers were the result of his years of experience in locomotive design and maintenance.

Mr. Kiesel is an active member of the American Railway Association and has served on many of its important committees and was Chairman of its Committee on Car Construction from 1912 to 1927.

In consideration of his numerous inventions of outstanding value in locomotive and railway car design and construction, THE FRANKLIN INSTITUTE awards its GEORGE R. HENDERSON MEDAL to MR. WILLIAM F. KIESEL, JR., of Altoona, Pennsylvania.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PURIFIED WOOD FIBERS.

SUPPLEMENTING previous work on permanence of alpha cellulose of pulps and half-stuffs, subjected to accelerated aging tests, samples of a new, white, rag half-stuff were treated with 1 and 3 per cent. bleach powder. These bleached samples thoroughly washed were made into hand-sheets and subjected to the usual 72-hour heat treatment at 100° C. Control and heated samples were analyzed for alpha cellulose content. The results which are tabulated below, check conclusively those previously obtained with the various grades of rag half-stuffs, and show clearly the effect of the presence of oxycellulose on the permanence of the cellulose fibers. Color permanence was also shown to be drastically lowered by the increased formation of oxycellulose.

Amount of Bleach, Per Cent.	Alpha Cellulose Content.		Loss in Alpha, Per Cent.
	Before Heating, Per Cent.	After Heating 72 Hours at 100° C., Per Cent.	
0	98.2	97.8	0.3
1	95.5	94.4	1.1
3	87.3	85.4	1.9

The viscosity determinations of the various pulps in copper ammonia solution before and after heat exposure are proving very interesting. In the viscosity determinations on sulphite, alpha cellulose, and old rag pulps, run to date, there seems to be a measurable drop in the viscosity curve (better, the time required for a certain volume under specified head to pass through a given orifice) of those samples which have been exposed. These results greatly strengthen the belief that the aging of cellulose pulps presents not alone a chemical change but also a physical one—a change in colloidal state, arrangement, or size of cellulose particle aggregation.

* Communicated by the Director.

Such changes, although they may be caused by or brought about by the chemical changes in the cellulose itself, may not necessarily show up by ordinary chemical determinations. This may be true even though basic changes have actually taken place in the pulps, changes which may seriously affect their use for permanent papers.

In the determination of the alpha cellulose content of the representative pulp samples before and after exposure to the 72-hour treatment at 100° C., the beta cellulose content appears to increase slightly as a result of the treatment. This increase probably bears some relation to the decrease in alpha cellulose content. However, with the data available, the bureau is not prepared as yet to say that the alpha cellulose loss is entirely converted into beta cellulose. In some instances the increase is not much greater than might be expected from experimental errors.

Papers have been subjected to various accelerated aging tests for the purpose of standardizing on the one best suited for permanence investigation. The following treatments were tried:

1. 100° C. in special circulating air oven for 24, 48, and 72 hours.
2. 95° C. in circulating oven in presence of humidified air for 72 hours.
3. Steam at atmospheric pressure for 2 hours.
4. Exposure to actinic rays from arc lamp. In preliminary work with the light test considerable difficulty was encountered in maintaining the humidity cabinet at sufficiently low temperature because of radiated heat from the arc. Various cooling devices are being tried in order to obviate this difficulty.

The test at 95° C. in humid air offers no particular advantages over the 100° C. exposure, and can undoubtedly be discarded. The 72-hour treatment at 100° C. seems to be by far the most convenient and satisfactory test, the two-hour steam treatment offering only one advantage, e.g., the short time required for its completion.

The entire series of submitted paper samples has been heated at 100° C. for 24, 48, and 72 hours and tested, together

with control samples for bursting strength, tensile strength, tear, and folding endurance. The 100 per cent. rag papers and alpha fiber papers show slight, and in most cases, no drop in bursting strength after heat treatment. Sulphite and 50 per cent. rag paper are, however, affected appreciably in this respect. The tensile strength is only of slight interest, even sulphite papers suffering no drop. The tearing test apparently is of some importance. Rag papers and alpha fiber papers show the highest retention of tearing force, rag and sulphite mixtures are next, while all-sulphite papers are most affected by the heat treatment. Judged by this test, sized papers are more permanent than unsized papers, the reverse being true in the case of fold retention. There is a fair degree of correlation between tear retention and fold retention. With very impermanent papers the tearing force is markedly lowered. However, the drop in folding endurance caused by a 72-hour heat treatment at 100° C. seems to offer the best indication of relative permanence of the various papers.

BOOKBINDING LEATHERS.

IN coöperation with the New York Public Library a series of tests was made on samples of bookbinding leather treated and aged under the following conditions:

(*A*) Exposed to gas light and gas fumes for 2600 hours at 90° F.
(*B*) Same as (*A*) but treated with a mixture of 40 per cent. anhydrous lanolin and 60 per cent. neutral neatsfoot oil.
(*C*) Exposed to direct sunlight and air for 240 hours and daylight for 900 additional hours at average temperature of 90° F.
(*D*) Same as (*C*) but treated with the above mixture of oil.

From each of the samples three test pieces were cut and the results were the average of three individual tests.

The test results show very definitely that the original leathers were seriously damaged when subjected to gas fumes excepting one sample which showed only a normal difference in strength when compared to the original leather. One sample showed complete deterioration.

Exposure to light alone gave erratic results. In two samples there was little change and in two there was an unexplained increase in tensile strength, all the others showed some deterioration.

Exposure of the treated leathers to gas fumes also gave erratic results. In three samples there was an increase in strength while in all other cases there was a decrease.

Exposure of the treated leathers to light showed an increase in strength of all samples except one which remained the same.

Whereas the results given for the leathers treated with oil show the effects of the exposures in relation to the original strength of the leather, it is probable that the figures would be different if oil treated leather had been available on which original tests could have been made. The general effect of oiling leathers is to increase the tensile strength.

DRYING OF OILS.

Some interesting experiments were made during the month on the drying of various oils as influenced by the light from the carbon arc. It was reported last month that linseed and tung oils would dry in the carbon arc in two hours as compared with several days in ordinary diffused light. This month many more oils were tested. Perilla oil set to touch in two hours. Oils such as candlenut, poppyseed, menhaden, and soya bean set to touch in four to seven hours. The so-called semi-drying oils, corn, cottonseed, and rubber seed oils, were found to dry in about 24 hours. In all cases the drying seems to be remarkably accelerated by the action of the carbon arc light. Films of the same oils are being exposed to diffused light in a drying cabinet. The linseed, tung, candlenut, perilla, and poppyseed became dry to the touch after four days under these conditions.

DETERMINATION OF SMALL AMOUNTS OF MOLYBDENUM.

In tests of the KCNS-reduced molybdenum method for the colorimetric determination of small amounts of molybdenum

(which is used in the analysis of the bureau's standard samples) it has been found that the compound formed is one of quinquevalent molybdenum, and not of trivalent molybdenum as claimed by Krauskoff and Swartz (*Journal, American Chemical Society*, Vol. 48, p. 3021; 1926). Reduction of the molybdenum by zinc and acid or by stannous chloride, as generally specified, is not satisfactory as these gradually reduce molybdenum beyond the quinquevalent stage. A new method of reduction is being worked out, with most encouraging results.

LACQUERS FOR WEIGHTS.

THE bureau is now beginning a comparative study of the amount by which various lacquers change in weight with ordinary changes in the humidity of the atmosphere. A large number of uniform sheets of brass have been made for the preparation of samples, and it is expected that observations on the first of these will be started very soon.

As a part of this work, the bureau hopes to have some samples prepared by the various manufacturers of lacquered weights. Sheets for the preparation of a few samples will be furnished such makers as are willing to supply rather complete information concerning the material and methods used. The names of those who furnish such samples will not be published, but the bureau must be free to publish the results, together with the method of applying and treating the lacquer, and its composition, or other satisfactory methods of identifying it. These samples will be investigated by the bureau free of charge, and full reports on the results will be furnished at once to the maker who supplied each sample. It is hoped that this investigation will be of immediate assistance to these manufacturers in the selection of the most satisfactory material for lacquered weights. Sheets for the preparation of two samples have already been furnished one manufacturer.

FADING PHENOMENA TO BE STUDIED ON BYRD ANTARCTIC EXPEDITION.

L. V. BERKNER, Assistant Radio Engineer, Bureau of Standards, is now on board the ship *City of New York* of the

Byrd Antarctic Expedition en route to the antarctic regions. Mr. Berkner, in addition to his duties as a radio officer of the expedition, will make an investigation of fading phenomena, particularly of high-frequency transmissions. The equipment for this work consists of two special high-frequency receiving sets loaned by the Westinghouse Electric and Manufacturing Company to which fading recorders have been adapted by the bureau. These recorders are similar to those used by the Bureau of Standards in previous fading investigations, and the method used will be the same.

It is expected that this investigation will give information on the effect of the concentration of the earth's magnetic field at the south magnetic pole, of auroras, temperature, height of the radio reflecting layer, and many other phenomena which affect radio transmission. Mr. Berkner will make observations upon selected stations, and some special transmissions may be arranged.

The expedition will be in the antarctic regions for sufficient time to give observations throughout both the daylight and dark months of an antarctic year. The bureau will keep in touch with the work by means of radio communication.

FILTERS FOR CHANGING THE COLOR TEMPERATURE OF INCANDESCENT SOURCES TO MEAN SUNLIGHT.

IN connection with an extensive investigation leading to the development of a large number of reproducible liquid filters for converting the color of incandescent light sources to sunlight and other high color temperatures, a filter was designed to convert the color and energy distribution of an incandescent Mazda C lamp at 2848° K. to that of the sun outside of the earth's atmosphere. It was hoped that this might serve as a suitable daylight filter, inasmuch as but little of the sun's energy (in the visible spectrum) is selectively absorbed by the atmosphere. In other words the relative spectral energy distribution of the sun outside the atmosphere should be closely like that of the sun plus blue sky or like that of an overcast sky.

The color of this source and filter combination has been compared with that of overcast sky on several days between

September 14 and September 29, 1928, the autumnal equinox period. At certain times on four different days the natural and artificial daylight were in practically perfect color match. At other times the natural daylight was slightly yellowish, purplish, or bluish, relative to the standard.

Standard artificial daylight is thus available, accurately reproducible from specification, and may be readily prepared in any laboratory. The specifications of this filter are similar to those of other Davis-Gibson filters. The exact proportions of the ingredients are as follows:

A.

Copper sulphate ($CuSO_4.5H_2O$)	3.125 grams
Mannite ($C_6H_8(OH)_6$)	3.125 grams
Pyridine (C_5H_5N)	30.0 ml.
Water (distilled) to make	1000.0 ml.

B.

Cobalt ammonium sulphate ($CoSO_4.(NH_4)_2SO_4.6H_2O$)	25.470 grams
Copper sulphate ($CuSO_4.5H_2O$)	25.000 grams
Sulphuric acid (Sp. gr. 1.835)	10.0 ml.
Water (distilled) to make	1000.0 ml.

One centimeter of each of solutions *A* and *B* are contained in a double cell having three plates of borosilicate crown glass (refractive index, D line = 1.51) each 2.5 mm. thick.

Complete spectrophotometric data will be sent upon request.

MEASUREMENT OF ELASTIC STRAINS IN CONCRETE STRUCTURES.

A TEST has been made recently to determine the practicability of a method which could be used in field tests of concrete structures, for distinguishing between the elastic strains produced by stress and those resulting from changes in temperature and humidity and from plastic flow or yield. In this method small blocks of concrete are cut out of the structure, measurements are made of the elastic recovery which takes place in these blocks as they are relieved from the forces acting when in the mass. The changes in strain accompanying the removal of the blocks were determined readily by means of a hand strain gauge. To facilitate the removal of the blocks it was suggested that each should be cast in a U-shaped trough or form. The principal object

of the test was to determine whether the presence of the form material would appreciably affect the strains in the block and whether the block could be cut out without injury to the gauge lines.

A concrete prism 30 by 30 inches in cross section and 36 inches in height was made for the test. The prism contained one removable block near the mid-point of each of the four lateral faces. Each block was in the form of a prism 5 by 5 inches in cross section and 20 inches in height. One of the forms for shaping the blocks was made of sheet metal about .03 inch in thickness. The other three were made of wall board of three different thicknesses. All were given a thin coat of paraffin to prevent bonding with the concrete. Plugs were set in the concrete for use in taking strain gauge readings in three gauge lines on each lateral face of the prism, one gauge line being in the removable block and the other two midway between the edges of the block and the prism.

The prism was placed in a testing machine and a compressive load of 600 lbs./in^2. applied. After taking strain readings one of the blocks was removed by cutting the concrete along each end of the block. Although this required a cut about 5 inches in length and 5 inches in depth along each end of the block these were made easily with a small air drill. The load on the prism was then released and strain gauge readings were made. The same operation was followed in removing another block from the prism.

The results of the tests indicate that the blocks, when separated (except at the ends) from the prism by thin forms, were cut out without a noticeable injury to the gauge lines. It was found, however, that the strain in the block cast into the sheet steel form was only about 70 per cent. of the average strain in the adjacent gauge lines, whereas for the blocks cast into wall board forms the strains were on the average about 30 per cent. greater than in the adjacent concrete. These results indicate that some provision should be made when using metal forms to prevent the steel form taking such an appreciable amount of stress as to affect the strain in the concrete block. They show further that wall board on account of its greater thickness and lack of rigidity is not a suitable material for such forms. Apparently, the method

can be made practicable for separating the elastic from the inelastic strains measured in concrete.

REPORT OF STANDARD ZETTLITZ KAOLIN TEST.

AT its Copenhagen meeting, the International Union of Pure and Applied Chemistry voted to undertake the preparation and distribution of an international standard sample of Zettlitz kaolin and charged the Ceramic Society of Czecho-Slovakia with the duty of carrying out this resolution. This society established a permanent committee to prepare, distribute, and to act as custodian for this standard sample. Samples of this standard may be secured by application to The Ceramic Society of Czecho-Slovakia, Prague, Czecho-Slovakia. Samples of this standard have been distributed to the countries belonging to the Union for analysis and test, and it is hoped that a comparative study of the results obtained will lead eventually to the adoption of international methods for the analysis and testing of clays for ceramic purposes.

The present report contains the results obtained in the study of the standard kaolin at the Bureau of Standards made in accordance with the methods adopted by the American Ceramic Society and also other methods in use at the bureau.

CHEMICAL ANALYSIS.

	Per Cent.
Silica (SiO_2)	46.90
Alumina (Al_2O_3)	37.40
Ferric oxide (Fe_2O_3)	.65
Phosphorous pentoxide (P_2O_5)	.08
Titania (TiO_2)	.18
Zirconia (ZrO_2)	.007
Manganese oxide (MnO)	.007
Calcium oxide (CaO)	.29
Magnesium oxide (MgO)	.27
Barium oxide (BaO)	.02
Strontium oxide (SrO)	.006
Chromic oxide (Cr_2O_3)	.015
Vanadium trioxide (V_2O_3)	.002
Potassium oxide (K_2O)	.84
Sodium oxide (Na_2O)	.44
Sulphur trioxide (SO_3)	.03
Loss on ignition (1050–1100° C.)	12.95
Total	100.087

SUMMATION OF PHYSICAL TESTS.

Test.	Clay.	50/50 Clay-Flint Mix.
Softening point	Above cone 34 (1755° C.)	
True specific gravity	2.633	
Dry volume shrinkage	25.8 per cent.	16.1 per cent.
Dry linear shrinkage	7.9 " "	5.1 " "
Water of plasticity	46.4 " "	29.8 " "
Shrinkage water	17.1 " "	10.4 " "
Pore water	29.3 " "	19.4 " "
Dry transverse strength	261 lbs./in².	116 lbs./in².

In the determination of the firing behavior, values were obtained on specimens of clay and of 50/50 clay-flint mixtures fired to cones 2, 4, 6, 8, 10, 12, 14, 16, and 18. Only the results at cone 12 are reported herewith.

Test.	Clay.	50/50 Clay-Flint.
Porosity	25.4 per cent.	32.0 per cent.
Fired volume change	33.35 " "	8.75 " "
Linear change	12.75 " "	3.35 " "
Apparent specific gravity	2.545	2.555
Bulk specific gravity	1.90	1.75
Absorption	12.9 per cent.	17.5 per cent.
Fired transverse strength	4,290 lbs./in².	1,660 lbs./in².
Modulus of elasticity	5,911,000 lbs./in².	
Coefficient of expansion per degree Centigrade (Interferometer method)	6.74×10^{-6}	12.94×10^{-6}

A detailed report of the tests made, and of the apparatus and methods used in making the tests, is being prepared and will be available in the near future.

SPARK ACCELEROMETER.

IN the course of current work on motor fuel research, it has been necessary to devise apparatus of increased precision for the measurement of automotive engine acceleration.

The acceleration of interest is that occurring in the short interval after the throttle is opened before the engine attains full speed. At first this was obtained from successive readings of a chronometric tachometer. However, in addition to being inaccurate and involving the personal equation, the tachometer, reading only once a second, obscures some transient phenomena.

The apparatus devised to overcome these difficulties is constructed almost entirely of parts commercially obtainable at low cost. It consists of a sprocket, coupled to the engine through a one-position claw clutch, which draws paper tape, of the same size and with the same perforation as 16 mm. motion picture film, between electrodes across which a spark is periodically discharged. This spark is timed by a tuning fork, which breaks the primary circuit of an automobile ignition coil. The record consists of a series of holes in the tape, the distance between any two holes being proportional to the mean engine speed in that time interval.

In order to facilitate measurement and computation of the results, the tuning fork was adjusted to give a frequency of 360 cycles per minute. Measurement is made by passing the tape over a sprocket identical with the one attached to the engine. A microscope is trained on the tape, and the sprocket is revolved until a spark hole is under the cross hair. Reading is made on a micrometer head graduation in degrees which is carried on the sprocket shaft. Since the tuning fork splits a minute into 360 parts and the micrometer head splits a revolution into 360 parts, differences of successive readings give revolutions per minute directly.

Strictly speaking, the data give only displacement and time precisely, and acceleration is obtained only approximately by double numerical differencing. Mathematical analysis shows, however, that the error thus introduced is negligible for the purposes of the present investigation. With this apparatus, speed can be measured six times a second, with a probable error for a single measurement of less than 1 r. p. m.

STANDARDIZATION OF DIESEL ENGINE FITTINGS.

Plans for standardization in the Diesel engine field are described in a bulletin of the American Society of Mechanical Engineers. The bulletin points out that certain small parts, such as piston rings and spray valves, are manufactured by specialty concerns and that standardization would enable these manufacturers to contribute largely to the reduction of engine-making costs. A committee of the oil and gas power division is at work on the subject.

Eggs. E. M. BAILEY (Connecticut Agric. Ex. Station Bulletin 295, 314–315, 1928) states that large air spaces accompanied by low ammonia content indicate eggs held at low temperatures or in cold storage. Large air spaces accompanied by high ammonia content indicate eggs held under less favorable conditions, e.g., those held too long by either the producer or the retailer.

J. S. H.

Use of Carbon Tetrachloride plus Air for the Decomposition of Sulphides and Related Compounds. K. BRADDOCK-ROGERS (Thesis, Graduate School, Univ. of Penn., 1928, 1–21) has devised the following procedure for the preparation of sulphur-free carbon tetrachloride. He treats 3 parts of carbon tetrachloride with 2 parts of a 1 : 1 mixture of ammonia water and sulphate-free hydrogen peroxide, repeats the treatment several times, dries over calcium chloride, and distils. The entire process is repeated until a product is obtained which is shown to be sulphur-free by the following test. The carbon tetrachloride is kept at a temperature of 60° to 65° C.; one liter of air, free from carbon dioxide and moisture, is drawn through it in 40 minutes; and the gaseous mixture is heated to a temperature of 750° to 800° C., then passed into ammoniacal hydrogen peroxide solution which is free from sulphates. The resulting solution is boiled to expel the excess of ammonia, acidified with hydrochloric acid, and tested for the presence of sulphates with barium chloride solution.

Certain sulphides, selenides, and tellurides were completely decomposed and chlorinated by treating them with a mixture of air and vapor of the sulphur-free carbon tetrachloride at elevated temperatures. Of the sulphides, sphalerite, pyrite, cinnabar, bismuthinite, chalcopyrite, nickel matte, copper matte, and palladous sulphide were decomposed, and their sulphur content rapidly and conveniently oxidized prior to quantitative determination of that element. Pyrrhotite, marcasite, arsenopyrite, stibnite, tetrahedrite, cobaltite, molybdenite, galenite, enargite, sylvanite, and tiemannite were completely decomposed, but the quantitative determination of their sulphur or selenium content was not made. The procedure was also used for the complete decomposition of the selenides, berzelianite and zorgite, and of the telluride altaite, and the quantitative determination of their selenium and tellurium, respectively.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

QUANTITATIVE RELATIONS OF THE COUNTER-CURRENT WASHING PROCESS.[1]

L. Silberstein.

A MATHEMATICAL treatment of the so-called counter-current process of widespread use in chemical manufacture. The general conditions of the process are expressed in the form of recurrence equations. By means of these equations the cases of a three-tank, a four-tank, and a five-tank system are dealt with in detail, and formulas are developed giving directly the concentration of the solute in each tank after any number of operations, including the limit-values of the concentrations for an indefinitely continued working of the process.

* Communicated by the Director.

[1] Communication No. 340 from the Kodak Research Laboratories and published in *Ind. Eng. Chem.* **20**: *899. 1928.*

Respirators for Protection Against Poisonous Sprays.—(United States Public Health Service.) Surgeon General H. S. Cumming, of the U. S. Public Health Service, has recently announced (Public Health Bulletin No. 177) the results of an investigation undertaken at the request of a committee appointed by the National Safety Council. This investigation has been made by the United States Bureau of Mines and the National Safety Council in cooperation with the United States Public Health Service to determine the value of respirators as a means of protection from the hazard of spray painting resulting from exposure to lead, benzol, and silica. The specific questions proposed by the National Safety Council to be answered were as follows:

1. What filtering material, if any, is adequate?
   (*a*) To reduce the lead content of the air to which a spray coater is exposed from 200 milligrams per cubic meter to 0.6 milligram per cubic meter?
   (*b*) To reduce the amount of benzol under similar conditions from 2,000 to 75 parts per million?
   (*c*) To reduce the number of silica particles under similar conditions from 200,000,000 to 100,000 per cubic meter as determined by the Palmer method?
2. How long would such a layer function?
3. How do certain typical masks now available measure up to this standard?

The concentrations stated above for lead and benzol should not be construed as being those to which spray painters are commonly exposed. They represent more nearly the high concentrations which can quickly cause sickness and are to be considered as extremes.

It may be stated, as a result of the tests, that in general the respirators with cotton, paper, or fabric filters remove 90 per cent. or more of the lead from air carrying paint mist. These respirators restrain none of the solvent vapors, however; but the addition of a canister or cartridge of activated charcoal to the respirator removes all solvent vapors until the charcoal becomes saturated.

The useful life of filters is determined by their increase in resistance, which necessitates changing for fresh filters at intervals of several hours. When charcoal is saturated, the cartridge must be exchanged for a fresh one. Canisters of the size used with gas masks may last for weeks before a change is necessary.

The respirators were somewhat less efficient against the silica dust sprays, but they restrained 24 per cent. or more of the dust from the air passed through them; most of them were more than 50 per cent. efficient.

NOTES FROM U. S. BUREAU OF MINES.*

NEUTRALIZATION OF ACID MINE WATERS.

THE neutralization of acid mine waters, which drain into rivers and creeks, thereby constituting a serious sanitary problem, can be successfully accomplished, so far as chemical and mechanical factors are concerned, declares the United States Bureau of Mines. The final problem is, however, one of economics. In that aspect, it must be considered separately for specific sections or communities. The factors involved are of such a nature that one hard and fast rule can not be applied with equal satisfaction to all cases.

The pollution of streams has received much attention during the last few years, and although there are many other and more serious forms of pollution, the problem of acid mine drainage is important in certain sections of the country, particularly in Pennsylvania. At the request of the United States Public Health Service, the Bureau of Mines undertook to determine some of the factors contributing to formation of acid mine waters, the yearly variation in quantity and quality of drainage, effect of mining methods, and various other questions arising in connection with the problem; some attention was also given to its economic phases.

A stream having a number of mines draining into it was selected for observation in both high-sulphur and low-sulphur bituminous-coal districts. These mines and streams were visited in both wet and dry seasons to note the quantity and variations in acidity of mine drainage and the subsequent effect on streams. The streams were sampled at regular intervals of about one-half mile, unless entering streams or unusual conditions warranted more frequent samples.

Mine samples showed wide variations in acidity, but indicated that drippers and samples from fresh working faces were almost invariably alkaline or but faintly acid because of the presence of bicarbonates or dissolved carbon dioxide in the

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* Published by permission of Director, United States Bureau of Mines.

water. On the other hand, water from inactive or abandoned sections was almost invariably acid to a degree determined largely by the period that the sections had been idle.

Gobbed material, both inside and outside the mines, is undoubtedly an important source of acid water; but whether the practice is to gob rock and high-sulphur coal inside or outside the mine, the general acidity of the water from the different mines does not show appreciable differences. Outside gob piles are under the most favorable conditions for liberating acid, more so than if the gob material were inside; therefore it seems that less damage would be done if the acid-forming wastes were left inside. If gob material could be placed in dry sections of the mine and sealed off to exclude air, the minimum formation of acid might be expected.

Water from mines having a limestone floor would be expected either not to be acid or at least to be less so than water from mines in the same district not having a limestone floor. No marked difference has so far been observed in such waters, probably because after a short time the drainage channels become coated with iron oxide which adheres tenaciously to the stone and protects it from contact with the water.

Water from high-sulphur-bearing coal beds is more acid than that from low-sulphur beds.

Abandoned workings are known to have given off water of approximately the same quality and quantity up to at least 15 years after being abandoned. One abandoned mine has been giving off highly acid water for 45 years to date; no caving has yet occurred in this mine. Four others exhibit the same characteristic after having been abandoned 35 years. Twenty-five abandoned workings showed about the same acidity as eight active mines in one district studied, but in the other district seven abandoned mines showed only about one-half the acidity of the other 17 active mines.

Seasonal variations play an important part in the effect of mine drainage on streams. The maximum stream volume at flood stage in such localities as those studied may be many times the average volume because of the rapid run-off. Heavy rains of short duration, therefore, dilute the water to the extent that it may be considered harmless; mine drainage is not in general increased unless slower soaking rains occur. On the

other hand, at periods of low water, usually in August or early September, the stream volume may be, and often is, almost entirely mine drainage.

So far little opportunity has been afforded for observing the effect of a definite quantity of acid in streams. With one exception, the entry of drainage from successive mines resulted in building up an acidity which decreased only slightly until the stream entered a small river.

At the present time there seems to be no solution of the problem of stream pollution other than that of chemical neutralization. One method that might be used to treat large volumes of water is to feed ground limestone or lime to the raw water, using a baffled flume to mix the lime well, and then permitting the water to flow into natural or artificial settling basins of sufficient capacity to retain the water for four or five hours. During this time the hydrated oxides of iron will settle out and the effluent water will be neutral or alkaline, somewhat harder, but almost clear, and harmless for most purposes if the treatment is carefully controlled. Of the methods now in use this is the cheapest in first cost and the most simple in operation, but it leaves the sludge as a material too thin to shovel and too thick to pump. Its subsequent removal and disposal is likely to prove as much of a problem as the original acid neutralization now appears to be.

The solution of the problem of drainage disposal after coal areas have been mined out and acid water still continues to flow for an indefinite time is also uncertain. One possible solution is to seal abandoned mines as so to exclude the air and thus prevent further oxidation of the pyrite. It seems likely that water from such mines would become pure again in less time than if they were not sealed.

Considerable improvement in certain sections that are now being polluted by water from abandoned workings might be accomplished by sealing the mines; the cost would not be great and the process does not appear difficult in most cases. The sucess of this scheme seems very probable because it has repeatedly been shown that where abandoned mines are sealed either by natural caving or by building seals, the water is suitable for all ordinary uses, sometimes even for drinking water.

MANUFACTURE OF WAX CRAYONS FROM COAL TAR.

The suitability of wax extract from coal tar produced in the low temperature carbonization of coal for use as a base in the manufacture of colored wax crayons is being investigated at the Pittsburgh Experiment Station of the Bureau of Mines. Several commercial colored crayons have been analyzed and similar crayons have been made up using the tar wax. From experiments so far made this wax appears very well suited to the purpose. It has a high melting point, which doubtless will render its use advantageous in making crayons for particular purposes.

FUSAIN IN PITTSBURGH COAL.

A general investigation of the inert materials in Pittsburgh coal of the Youghiogheny district is being made by the Bureau of Mines. In the course of this work it is found that the fusain or mineral charcoal, is distributed in thin partings quite widely over the whole bed, that is, in some localities most of it will be found at the top of the bed and in others at the bottom or in the middle. Some of these fusain partings are quite hard due to a high calcium carbonate content, whereas others are soft and contain very little calcium carbonate. The total fusain content in the main coal seam of one mine was found to be of the order of 3.5 per cent. It has been shown that segregated fusain in a coking coal has a very deleterious effect on the coke produced therefrom. It weakens the coke structure. The precise effect of evenly distributed fusain, however, has not been determined.

LESS FINELY CRUSHED GRAINS NOW YIELD TO FLOTATION.

It has generally been held that for the treatment of ores by the flotation process, crushing to minus 65 mesh is required. This was the size limit of grains which experience seemed to indicate, when only oils were used chiefly. Experimental work at the Moscow, Idaho, field office of the Bureau of Mines shows that sands crushed to not nearly this degree of fineness can be readily floated. In some of the work at that station, as coarse as 20 mesh sands are amenable to flotation. Even coarse sands that expose at their surfaces very small specks of the floatable mineral may be lifted.

This broadening of the field of flotation is due to the development in recent years of the "promoter" class of reagents. These substances so greatly increase the flotative vigor of a mineral that correspondingly larger grains may be lifted. Flotation is rapidly moving into the size range of table concentration and the cost of crushing for flotation gradually being reduced.

CALORIMETRY OF METAL OXIDES.

A new type of calorimeter for the study of metal oxides has been developed at the Pacific Experiment Station of the Bureau of Mines, Berkeley, California, and is now being operated at that station. Despite the great technical importance of data on heats of oxidation of common metals, little work on the subject has been done in recent years. Classical values used by metallurgists or chemists often date back more than 50 years. Modern requirements, especially for critical thermodynamic studies of smelting processes, necessitate more accurate determinations.

The bomb type of calorimeter, in which metal is burned with oxygen under pressure, although of great practical use for fuels, is unsuitable for metals when high accuracy is desired, and indirect methods are preferable. The chief of these is calculation from measured heat of solution of metal and oxide in the same concentration of acid. Ordinarily oxides are rapidly and metals slowly dissolved by acids. The new calorimeter has been specially designed to enable both types of determinations to be made in the same instrument, thus assuring comparable results for oxide and metal.

An unusual feature of the Bureau of Mines' calorimeter is a small built-in boiler in which ethyl bromide is evaporated at 25° C. at a rate just sufficient to neutralize the heat of solution of the metal. In this way experiments of many hours' duration may be made with negligible undeterminable loss of heat. The amount of ethyl bromide evaporated is weighed and the heat calculated therefrom, even though actual temperature change did not occur. Corrections necessary with other methods, involving the heat content of the calorimeter, are thus avoidable, or become satisfactorily minute.

Separation of Aluminium and Beryllium. I. M. KOLTHOFF and ERNEST B. SANDELL of the University of Minnesota (*Jour. Am. Chem. Soc.*, 1928, *50*, 1900–1904) recommend the use of ortho hydroxyquinoline for the separation of aluminium and beryllium. A 5 per cent. solution of the reagent is prepared, using double normal acetic acid as the solvent. The solution of aluminium and beryllium should be only slightly acid; it is warmed to a temperature of 50° to 60° C.; an excess of the solution of ortho hydroxyquinoline (also called oxine) is added; then double normal ammonium acetate solution is slowly added until a permanent precipitate forms and a large excess of this reagent is present. The aluminium is precipitated as its salt of ortho hydroxyquinoline, which has the formula $Al(C_9H_6ON)_3$ and contains 11.10 per cent. of alumina, Al_2O_3, when dried at 120° to 140° C. Beryllium remains in solution. The beryllium may be precipitated in the filtrate from the aluminium by means of ammonia after heating almost to boiling.

J. S. H.

Acetic Acid as a Solvent. ARTHUR W. DAVIDSON of the University of Kansas (*Jour. Am. Chem. Soc.*, 1928, *50*, 1890–1895) finds that many salts, especially halides and nitrates, are soluble in pure acetic acid, while sulphates are very slightly soluble in that solvent. Reactions involving double decomposition occur quite readily in acetic acid solutions, but solvolysis does not take place to any marked extent.

J. S. H.

Origin of the Metal in Meteorites. GEORGE P. MERRILL (*Proc. U. S. Nat. Museum*, 1928, *73*, Article 21, 1–7) has evolved a theory concerning the origin of the metal in meteorites. Meteorites are volcanic products. They contain lawrencite or ferrous chloride. When first formed, large quantities of chlorides are present. The heated atmosphere of hydrogen or other reducing gas at the fountain source of the meteorite reduces chlorides to the metallic state.

J. S. H.

Occurrence of Carotin in Honey. H. A. SCHUETTE and PHYLLIS A. BOTT of the University of Wisconsin (*Jour. Am. Chem. Soc.*, 1928, *50*, 1998–2000) have isolated at least one of the pigments of buckwheat honey by means of petroleum ether in the presence of ethyl alcohol and calcium sulphate, and have identified it as carotin.

J. S. H.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, October 17, 1928.*)

THE stated monthly meeting was called to order at eight-eighteen p.m. by Mr. Henry Howson, Vice-President.

The Secretary announced that the minutes of the last stated meeting, the Medal Day meeting held on May sixteenth, had been published in full in the June number of the Journal and that an extended description of Medal Day exercises had been published in the Journal for August. He therefore moved that the minutes and description of the meeting be approved as printed in the Journal. The motion was seconded and unanimously adopted.

The Secretary made the following report concerning changes in membership which have taken place since the last stated meeting: Ten new Resident members, thirteen Non-Resident and one Student member, and eleven deaths, which are reported in the Journal.

There being no further business, the Chairman called for the paper of the evening, which was to be delivered by the Secretary of the Institute on "Present and Proposed Activities of The Franklin Institute."

The meeting adjourned at nine-twenty-eight p.m., after which a moving picture film made in the scientific museums of Europe a year ago was shown to the membership of the Institute.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, October 3, 1928.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, October 3, 1928.

DOCTOR GEORGE S. CRAMPTON *in the Chair.*

The following reports were presented for final action:

No. 2875: Ruths' Steam Accumulator.

The purpose of this device is to provide a means of storing steam in connection with a boiler plant in order to meet higher steam requirements without forcing the boilers beyond their rated capacity. To secure this result steel cylindrical storage tanks with hemispherical ends are provided in which water at a temperature above the atmospherical boiling point is stored.

Whenever the steam driven machines do not make use of the steam generated in the boilers, the excess steam passes through a one-way valve into the storage tank in which it is forced into water through distributing pipes raising both the temperature and pressure of the water.

Whenever the machines demand more steam than the boilers provide, steam from the storage tank passes through an outlet valve to supply the deficiency.

This steam accumulator is extensively used in European countries and is being introduced in the United States.

This report recommended the award of the John Price Wetherill Medal to Doctor Johannes Ruths of Djursholm, Sweden, "In consideration of the excellence of design of the control equipment and the adaptation of sound principles to the successful production of large steam storage apparatus."

No. 2893: Gas Carburizing Apparatus.

The use of this method is for carburizing, carbonizing, or case hardening steel articles by means of a rotary carburizer which is heated by gas and is kept in rotation during the process.

The articles to be carburized are placed in the retort, the carburizing compound or gas is then added and the fuel gas applied. The temperature at which carbonization begins is about 1350 degrees F. and the depth to which the hardening extends is approximately proportional to the time of operation.

The furnace in which the process is carried on is supported on an axle extending crosswise upon which it can be tilted. For loading it is tilted with the mouth upward, for carburizing it is kept horizontal. When the operation is finished it is tilted with the mouth downward to empty the contents into a quenching tank.

This report recommended the award of the Edward Longstreth Medal to Mr. Adolph W. Machlet, of Elizabeth, New Jersey, "In consideration of his improved method of case hardening and the construction of the apparatus for that purpose whereby the cost of case hardening is reduced, a greater uniformity of hardened surface secured and the quality of the work kept under control and thereby improved."

The following report was presented for first reading:

No. 2883: Monroe Calculating Machine.

GEORGE A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, October 10, 1928.*)

RESIDENT.

DR. JOHN MCARTHUR HARRIS, JR., Chemical Engineer, Sun Oil Company, Norwood, Pa. For mailing: 105 West Walnut Lane, Philadelphia, Pa.

MISS ELISE NACHMAN, Teacher, Fitzsimons Junior High School. For mailing: 4617 Pulaski Avenue, Philadelphia, Pa.

MR. ALAN REED, Wyncote, Pa.

MR. JOHN R. WILLIAMS, President, Electric Storage Battery Co., Eighteenth Street and Allegheny Avenue, Philadelphia, Pa.

NON-RESIDENT.

MR. CLARENCE W. HANSELL, Electrical Engineer (Radio), Radio Station, Rocky Point, N. Y. For mailing: 115 Tuthill Street, Port Jefferson, N. Y.

MR. WILLIS A. NAUDAIN, Electrical Engineer, Meter Engineer, Delaware Electric Power Co., 834 Market Street, Wilmington, Delaware. For mailing: 304 West Fourteenth Street, Wilmington, Delaware.

DR. WILLIAM S. MASON, Banker, 1401 Ridge Avenue, Evanston, Illinois.

MR. DEL A. SMITH, General Manager, Department of Street Railways, City of Detroit. For mailing: 4373 West Philadelphia St., Detroit, Michigan.

CHANGES OF ADDRESS.

MR. FRANK AIKEN, 474 West Manheim Street, Germantown, Philadelphia, Pa.

DR. GELLERT ALLEMAN, Wallingford, Pa.

DR. H. D. ARNOLD, Bell Telephone Laboratories, Inc., 463 West Street, New York City.

MR. A. F. BABCOCK, Traffic Department, 1835 Arch Street, Philadelphia, Pa.

MR. CARL G. BARTH, 229 Park Avenue, Prescott, Arizona.

MR. A. W. BERRESFORD, 1 Fifth Avenue, New York City.

MR. STERLING H. BUNNELL, 27 William Street, New York City.

MR. HENRY H. COLLINS, 1518 Walnut Street, Philadelphia, Pa.

MR. JOHN F. CONAWAY, 1913 North Twelfth Street, Philadelphia, Pa.

MR. GEORGE M. DAVIDSON, 211 North East Avenue, Oak Park, Illinois.

MR. JOHN F. DREYER, JR., 232 West Walnut Lane, Germantown, Phila., Pa.

MR. WILLIAM DUBILIER, Patents Corporation, 10 East Forty-third Street, New York City.

MR. CLARENCE ERROL FERREE, Wilmer Ophthalmological Institute, Johns Hopkins Hospital, Baltimore, Md.

MR. EDWIN FRANK, 1023 Shepard Avenue, Milwaukee, Wis.

DR. F. W. FRERICHS, 4557 West Pine Boulevard, St. Louis, Mo.

MR. HARRY A. GOULD, 119th Street and Morningside Drive, West, Butler Hall, New York City.

MR. GEORGE R. HALL, Room 711, 50 Broadway, New York City.

MR. THOMAS W. HICKS, 1415 Thayer Avenue, Brentwood Heights Station, Los Angeles, California.

MR. L. H. KINNARD, Bell Telephone Company, 1835 Arch Street, Philadelphia, Pa.

MR. H. W. LILLEBRIDGE, 226 West Jackson Street, Philadelphia, Pa.

DR. JOHN M. MILLER, 1010 West Upsal Street, Germantown, Phila., Pa.

MR. JOSEPH W. MYERS, 205 South Webster Street, Jackson, Michigan.

MR. FOSTER NOWELL, Engineering Department, 1635 Arch Street, Philadelphia, Pa.

MR. H. H. PLATT, Boulevard Dominique Durandy, St. Jean Cap Ferrat Alpes Maritimes, France.

MR. C. H. QUINN, 541 Monadnock Building, San Francisco, California.

MR. TALBOT M. ROGERS, 6 South Dodd, Princeton, New Jersey.

DR. G. D. ROSENGARTEN, Malvern, Pa.

MR. JAMES L. SCHWANK, Alden Park Manor, Germantown, Philadelphia, Pa.

MR. F. R. SHUMAN, Bell Telephone Company, 1835 Arch Street, Philadelphia, Pa.

DEAN AUGUSTUS TROWBRIDGE, Princeton University, Princeton, N. J.

MR. E. T. TURNER, 170 North Beacon Street, Hartford, Conn.

MR. C. D. TUSKA, 717 West Mt. Airy Avenue, Mt. Airy, Philadelphia, Pa.

MR. S. M. VAUCLAIN, The Baldwin Locomotive Works, 123 South Broad Street, Philadelphia, Pa.
MR. WALTER C. WAGNER, Edison Building, Ninth and Sansom Streets, Philadelphia, Pa.
MR. J. E. WAIDLICH, Bell Telephone Company, 1835 Arch Street, Philadelphia, Pa.
MR. ALFRED E. WALLER, 110 White Plains Road, Bronxville, New York.
MR. E. R. WHITNEY, 6745 Lawnton Avenue, Oak Lane, Philadelphia, Pa.
DR. ROBERT H. WILHELM, 4537 Spruce Street, Philadelphia, Pa.

NECROLOGY.

Mr. Robert Anderson, Lansdowne, Pa.
Mr. Richard Greenwood, Frankford, Phila., Pa.
Mr. Charles H. Parkin, Cleveland, Ohio.
Mr. E. D. Williams, Philadelphia, Pa.
Mr. Henry W. Wilson, Philadelphia, Pa.

LIBRARY NOTES.

RECENT ADDITIONS.

ARENDT, MORTON. Storage Batteries. 1928.
Ausführliches Handbuch der Photographie. Band II, 4 Teil; Band IV, 1 Teil. Two volumes. 1928.
Beilstein's Handbuch der organischen Chemie. Vierte Auflage, erstes Ergänzungswerk, erster Band. 1928.
BOWIE, WILLIAM. Isostasy. 1927.
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DRAYCOTT, GEORGE EDWIN. Technical Drawing. 1927.
FRY, THORNTON C. Probability and Its Engineering Uses. 1928.
Handbuch der praktischen Kinematographie. Band III, 1 Teil, Die kinematographischen Projektion von H. Joachim. 1928.
HANNEKE, PAUL. Das Arbeiten mit kleinen Kameras. Enzyklopädie der Photographie und Kinematographie, Heft 85. 1928.
LAWRIE, JAMES W. Glycerol and the Glycols. 1928.
Master Boiler Makers Association. Official Proceedings of the Nineteenth Annual Convention. 1928.
PAPESCH, OTTO. Reifung von Bromsilbergelatine mit Ammoniak und Ammoniumkarbonat. Enzyklopädie der Photographie und Kinematographie, Heft 113. 1928.
Photographischer Notiz-Kalender für das Jahr 1928.
Royal Society of London. Philosophical Transactions, Series A, Volume 227; Series B, Volume 216. 1928.
SUGOT, G. Balistique Extérieure. Théorique. 1928.
SUGOT, G. Balistique Intérieure. Théorique et Tables Numériques. 1928.
SVEDBERG, THE. Colloid Chemistry. Second edition. 1928.

Who's Who in America. 1928–1929. Volume 15. 1928.
WILKINS, HAROLD T. Marvels of Modern Mechanics. 1927.
Zeitschrift für physikalische Chemie. Namen-und Sachregister zu den Bänden 102–125. 1928.

BOOK REVIEWS.

"TOWARDS THE OPEN." By Henry C. Tracy with an Introduction by Julian Huxley. xx–257 pages, 6 x 8¼ in., cloth. New York, E. P. Dutton & Co., 1927. Price, $3.50.

Every one knows that we are living in "a new age" and most well-educated persons agree that its chief characteristic is its interest in science. Philosophy and metaphysics have lost something of their charm for the thinker of today. He prefers facts and theories which keep close to facts. Hosts of books are being produced in the attempt to explain the world according to scientific theories and to build upon the basis of such explanations, programs for the advancement of both the individual human being and society as a whole.

"Towards the Open," by Henry Chester Tracy, is a book of this type.

Mr. Tracy is an American, his early education was in connection with a college founded by his father at Anatolia, in the Near East, followed by biological studies at Oberlin College in this country and later engaged in experiments in education at the Williams Institute, Berkeley, California. He has spent much time out in the open.

"Towards the Open" has been written carefully. The author has gathered knowledge covering wide segments of science, psychology, sociology, pedagogy, philosophy and religion; and made this so compact behind the words employed that entire sentences glow with the brilliance of the author's mind, as an incandescent lamp wire may shine from the power shot through it.

While one is reading these pages he must call continuously upon his own background of information in many different fields:

The author's observations may seem at times overponderous, or again a trifle sententious to the reader accustomed to the style in which articles on scientific subjects are usually written. But when the hand of an artist is revealed one readily overlooks a tendency which in a writer less skilled would be set down as a mere fussiness in verbal structure.

The Introduction to "Towards the Open" is by Julian Huxley. He premises that society is an organism in which coöperation and competition go hand in hand in what Morley Roberts calls a "hostile symbiosis."

"In so far as we men live on the organic level," continues Huxley, "we too must live in competition, patent or latent, with each other. True that on the mental or spiritual level this need no longer be so, and we can attain to complete coöperation. But the roots of our life are still organic, our lives and our enjoyments depend upon material objects, which cannot interpenetrate, cannot be in two places at once; so that it is not likely, in any state which we can even dimly envisage, that society will emerge from this condition of hostile symbiosis.

"That being so, it behooves us to organize our society so that the symbiosis is more effective, the hostility further below the surface, the regulation more complete.

"To take but one example, the course of economic events is marked by a recurrent series of 'slumps' and 'booms,' both of them inimical to steady economic progress, social advantage, and happiness. Each automatically generates the other; and so far no one has found a method of regulating their excesses. Such latitude is unthinkable to the physiologist. Over-production within the normal body, whether over-production by a particular gland, or the over-flooding of the blood with sugar released from store, is at once and automatically checked, and the normal balance preserved within astonishingly narrow limits."

The book has three parts as follows:

Part I Individuals as Social Units: Life: A Parenthesis; Significant Persons; Significant Societies; Aristogenic Evolution; Eugenics as a Personal Concern; Ethics and Population.

Part II Individuals as Organic Facts: Individuals as Organisms; Organisms as Perfectible; Socialized Ends; Schooling for a World-Stage; A Life of Education; A Critique of Satisfactions.

Part III Individuals as Creative and Spiritual: Concrete Personality; Artistic Intuition; A Unifying Principle; Humanism as Tolerance; A Natural Mysticism; Towards the Open: A Conclusion.

We quote a few paragraphs from the last chapter:

"Beginning with the cell, all of life is a fresh adventure for that cell as individual in the natural world. First, it inherits from two lines of parentage and not from one. Thus the sting of its encounter with an aline lineage is present from the start; was the condition of its development as embryo; remains operative in its invisible genes. Sting and stimulation continue all through the enlarging life, and are, literally, its destiny taking form. Until birth, and for some time afterwards, this spur and drive upon the primal inertia remains in the unconscious, under physiological control. Before a year is over the clash of heredities and the string of contacts are being recorded in the psyche. After that the world is a continual challenge to the conscious self. Innate tendencies are being rounded. New-waked impulses have to be tried on a surrounding envelope of persons and things. Each day is an adventure, and each day, to such an individual, is new. As the cells mature and become functional, new faculties awake, so that the newness is cosmic in its range of perception; space, time and matter are reflected in the 'microcosm.'"

"To be aware of one's social-natural environment in its changing multiplicity, to read beneath the surface-ripples significant movements of thought rather than a medley of accidents, is to bring that environment, as far as may be, under voluntary control. There is no known limit to what one poised centre of awareness—one person detached from the wheels of obsession but not from sympathetic intelligence—can do in and for a group."

"It is at this point that the science of the individual becomes also the science of society, of the group. Groups have been driven, as in the Children's Crusade, by undirected energy and by impulses that may have been fine enough in themselves. There are modern crusades equally stupid, and the Great Stupidity is to be ruled by a fraction of one's mind."

The position taken by Mr. Tracy is in the main a review of modern educational processes and a plea for their improvement. As such it is not subject to criticism from the point of view of the physical sciences. We may do well to ignore any minor criticism involving points which do not affect the argument.

We are not sure that the author would agree with our opinion that his entire thesis is best summed up in his chapter "A Life of Education." At any rate we believe we can give no clearer or fairer idea of the purpose disclosed in this book than to quote from that section the four remedial propositions laid down by Mr. Tracy. They are as follows:

"There are certain things for the individual, and we may say to him and to his parents that he can get them, in spite of the schools. Let him pursue them and forget his grades. They are:

"First, his own individuality, with a refusal to receive the rubber stamp.

"What does this mean to me? I should have him ask himself of every new exercise, idea, detail of material assigned. By asking that question continually, and refusing to consider what the teacher or text seems to want it to mean (except as one among several alternatives) he may keep alive his power of discrimination. His parents can help him to keep that alive. It is their one resource under the present calamity that has overtaken the schools;

"Second, a grounding in the principles of humanized science, as a prophylactic against erratic philosophies, conjectural nonsense, incantations and hocus-pocus of every sort. He may have to do the humanizing himself. Let those rare parents who are free from mental infatuations, and the few enlightened teachers who can discriminate between the sane and the unsound, consider what a problem he has there. It will tax their mental resources to keep pace with his problem, even while he is in his teens;

"Third, stimulation. He needs it. That is what literature is for, with art and music, letterless forms of the life-rhythms. The child knows best what he responds to. The adult may help him direct that response: into reflection, composition, into any active effort that converts it into the stuff of his life. The stimulation is commonly there, but not the guidance. This point leads directly to the next individualistic objective, which is,

"Fourth, expression; usually called self-expression. In reality it is the breaking crest of a wave that started eons ago, or in eternity. It is trivial in proportion as it expresses merely the self—a thing of the moment. It becomes more than that as it is subject to a deeper control. That control should begin to find its vehicle very early in the life of a child. It does find it: self-expression begins in look, laughter and voice; it ends in supreme genius or in simple, genuine acts of everyday life. The problem is to find what is genuine—or, as some would put it, expresses the 'deep self.' Hardly anything in mechanized education either evokes that or recognizes it when it comes.

"This last, then, is the concrete aim of education, so far as it concerns the individual. But note that it connects immediately with the social end of it all; for what is society but a collective organization designed to favour the genuine expression of its members, their deep selves, for the advantage and satisfaction of all."

JOHN W. STOCKWELL.

ELECTRIC WINDERS. A manual on the design, construction, application and operation of winding engines and mine hoists. By H. H. Broughton, M.I.Mech.E., M.I.E.E., etc. 402 pages, illustrations, plates, tables, quarto. New York, D. Van Nostrand Company, Inc., 1928. Price, $15.

Among the multiplicity of specialized types of machines which are employed in the mining industry, the mine hoist and its component elements, the develop-

ment of a very special form of elevator peculiar to that industry, apart from its fundamental principles, embraces many equally special problems of design. In point of magnitude, it may be noted, the speeds and power requirements of these hoists attain such values as 4,000 feet per minute with a rated motor-capacity of 5,000 horse power, dimensions which far transcend those of elevators of familiar type.

Under the title "electric winders" the author has gathered a comprehensive collection, it may fairly be said, of practically all that pertains to the mechanism of the hoisting plant and the conditions that affect its design. No other motive power than the universally adaptable electric motor is considered, public power-current being well nigh universally available. Failing of such a source of current, the author in a chapter on power supply, discusses applicable methods of power generation. As in any power consuming project, an essential preliminary is an analysis of the "duty cycle" of the winder or a graph of the power required plotted against time. Matters of this kind and the variety of arrangements of the mechanisms which may be employed in meeting assumed and derived specifications of performance are fully analyzed and illustrated by many diagrams and drawings of apparatus and details. The multiplicity of problems of mine-hoisting conditions, the detailed analyses of those problems, and the methods of meeting them are described at generous length by deduction from mechanical principles and an unusually copious collection of their numerical application to the details of systems taken from actual practice. The author evidently enjoys unsurpassed facilities for securing data on current practice of hoisting in English and African mines, and a rare capacity for its presentation in a book of encyclopedic character.

LUCIEN E. PICOLET.

"THE NEW UNIVERSE" (AN OUTLINE OF THE WORLDS IN WHICH WE LIVE). By Baker Brownell, Professor of Contemporary Thought, Northwestern University. x–455 pages, 6⅛ x 9¼, cloth. New York, D. Van Nostrand Company, 1926. Price, $4.

Dr. Brownell in a Note at the beginning of the volume says:

"The universe brewed in the kettle of this book presumes an interested and rather well acquainted taste for current problems and ideas. . . . For most persons Chapter II will be the peak of difficulty for the entire book."

This Chapter II is addressed to "The Components of the Material World: the relativity of space, time and motion. Einstein. The electrical structure of matter. The quantitative basis of the elements. The transmutation of the elements. Conservation. The quantum theory of energy." These 25 pages contribute the most to the thought of those who have "a taste for current problems." The remainder of the volume is the unfolding of the author's astute and beautifully fluid cogitations about the world and phenomena, highly colorful and literary.

Baker Brownell has a style somewhat like that of Henry C. Tracy in "Towards the Open." Both authors are students of science and philosophy and both have the skill to use words and phrases as the painter does his colors, in entrancingly contrasting tones and cadences. Here is an example:

"To accept the scientific world of atoms, electrons, vibrations, laws of

gravity and the like, as in real relation to the sensations of sound or color through which we observe them, is a coup d'etat of common sense that no amount of rational elaboration can verify."

The author evidently is much impressed with the idea of reality. He declares:

"The problem of the world in general is a problem of the real, but reality is no terse word set up for definition. . . . It is everyone's problem and the meditations on reality inherent in it inhabit every mind. . . .

"The search for a field of reference whereon the shifting elements of human experience, things, contingent events may be placed and coördinated has led many a philosopher to labor on this world in general with a good deal of hope. It is a problem in philosophical location, and the classical demand for external absolutes, ultimate organizations, supreme laws and monitors is inspired by the same locative needs that move the physicist in another field to demand absolute space, time, an absolute 'now,' a fixed world stuff. . . .

"Where reality is the problem, truth, an amanuensis, and knowledge, a maid servant, are not first in interest. Real things are many; we may know what they specifically are; we may find truths and diverse things. But the reality of them is not many: no substance, says Spinoza, is divisible. Reality is gratuitously here: but no one can say what it is. It is the world in general. . . .

"Reality leans against us like a wall of wind. . . .

"We must give up the idea that science can incorporate all reality in itself, and then the antithesis between the worlds of description and appreciation, between mechanics and ends will disappear (suggested to Brownell by Dewey)."

But we find that, after all, Dr. Brownell does not deal with one universe as a unified reality. He has the thought about reality nicely distinguished. It is in three compartments: the world of action, the world of spirit and the world of science.

"Across the diverse fields of discourse, of worlds of action, of spirit, of science, oneness is more difficult to trace and even more important," he explains. "The worlds bounce apart like tennis balls; systematic unities break down; external ultimates are futile; and what oneness there may be among them it is clear is not like these. . . .

"To say that 'worlds' of science, of the spirit, of action are dimensions of the universe is more a metaphor than an accurate proposition. But the world in general can only be suggested, and dimensional analogies will come as near to saying it, no doubt, as all the ghosts and legends and the trying of philosophers and scientists will ever come. The world may have dimensions, many of them, these at least are three."

Common thought, of course, supports this distinction between "the world of mind" and "the world of matter"; and many of the scholars of the day would follow Dr. Brownell with complete agreement in such discourses as this:

"The tools that science uses to describe this world cannot apply to being, and the scientist is right in refusing to treat as a descriptive problem, what primarily is not amenable to descriptive method. . . .

"What are the tools of science? With what instruments does it approach the world? They are different, it is sure, from the ways of the spirit. The one is intuitive and agglutinative; the other is rational and classificatory. The one realizes the self in things; the other distinguishes the self from things. . . .

"By hypothesis science is finite. It creates the finite, as it were; it selects the finite factors of the world from a chest where many other things may be available. That is all that reason and sensation are equipped to do."

From the title "The New Universe," one might be led to look for an effort to view all phenomena from one field of reference. The book does not do this. Perhaps the author shows his wisdom in not attempting to do it.

Certainly this volume commands the attention of all those who wish to keep alive to the problems of the day. It rewards the hunger for careful and correct discussion, clear thought, beautiful imagery.

The work is built as "Book I, Studies in Matter, the world as scientific fact; Book II, Studies in Social Policy, the world of human conduct and practical action; and Book III, Studies in Personal Values, the world of appreciations and spiritual interests." An Appendix offers a "Table of Key Ideas" (merely a summary of the contents of each of the 17 chapters). The list of References is complete and well arranged.

JOHN W. STOCKWELL.

A TEXT-BOOK OF INORGANIC CHEMISTRY. Edited by J. Newton Friend, D.Sc., F.I.C. Volume vi, Part 1. Nitrogen, by Edmund B. R. Prideaux, M.A., F.I.C., and Herbert Lambourne, M.A., M.Sc., F.I.C. 242 pages, illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1928.

The element nitrogen has perhaps attracted more attention in connection with the development of industrial chemistry than any other in the list. Its important relations to living tissues, and, in striking contrast, to high explosives, have caused a very large amount of research to be given to it in all great nations. In some respects it is a very remarkable element for in the free state it shows so little chemical activity that it seems to be allied to the group now called "the noble gases," but it is capable of developing high affinity, and many compounds showing great contrasts in properties can be found in the descriptive text books.

Nitrogen belongs to group five of the Periodic system, the members of which range from a typical non-metal to a typical metal. Nitrogen is associated in its special group with several elements capable of forming highly poisonous compounds, but the type of poisoning that these exhibit is different from that exhibited by most of the poisonous nitrogen compounds.

The book in hand discusses the general character of the members of group five, divided into two sub-groups, one beginning with vanadium and ending with a radium derivative, the other, the familiar series, nitrogen phosphorus, arsenic, antimony, and bismuth. The greater portion of the book is devoted to descriptions of the important nitrogen compounds. The many nitrogen derivatives in organic chemistry are, of course, not included. About thirty pages are devoted to the nitrogen-fixation. Since the series to which this volume belongs is descriptive chemistry, the important question of nitrogen-fixation is not treated extensively. For such treatment we must turn to the comprehensive manuals now available. The general make-up of the volume is, of course the same as that of the other members of the series now so well known to chemists, the printing and paper being of high class, the references to the literature extensive and in detail. A commendable feature of the reference is that the year as well as the volume is always given when the two data are available. Physical data are given in great amount

and there are brief but useful and interesting notes on the history of the compounds, and on the chemical principles that are involved.

HENRY LEFFMANN.

A TEXT-BOOK OF INORGANIC CHEMISTRY. Edited by J. Newton Friend, D.Sc., F.I.C. Volume X, The Metal-Ammines. By Miss M. M. J. Sutherland, D.Sc., F.I.C. 260 pages, illustrations, 8vo. Philadelphia, J. B. Lippincott Company, 1928.

The reviewer cannot avoid a preliminary allusion to the somewhat unusual instance that this bock on a very highly specialized department of organic chemistry is written by a woman. As to what women will accomplish in science and politics, now that these opportunities have been so freely opened to them, is still not certainly demonstrated. Men generally have been skeptical as to the results of the complete enfranchisement of women and the unrestrained opportunities for the education in association with men. Heine said sarcastically, "when a woman writes a novel she has one eye on her work and one eye on some man. There is only one exception to this, the countess Ida Hahn-Hahn. She has only one eye."

The reviewer, however, does not make any such insinuation as to the merits of the author of this volume, whose degree gives ample evidence of thorough preparation for the work. The usual expressions of obligation to others are given in the preface. The descriptive portion is preceded by chapters on general principles and valency. Considerable space is given to the general character of the compounds which as might be expected are very numerous and many very complicated. Their intricate structural formulas and spatial relations are presented by a large number of clear diagrams. The book, therefore, represents an enormous amount of study of the literature, careful sifting of it and comprehensive, vivid arrangement. It takes its place in the series to which it belongs and is worthy of every praise. A work so highly specialized will find only a limited number of readers but these will be greatly aided by having the data collected in a compact, easily accessible form, and presented in excellent type and printing. The volume contains also the very useful table of the dates of issues of leading journals.

HENRY LEFFMANN.

STORAGE BATTERIES, THEORY, MANUFACTURE, CARE, AND APPLICATION. By Morton Arendt, E. E., Fellow American Institute Electrical Engineers, Assistant Professor of Electrical Engineering, Columbia University. v–285 pages, illustrations, 23 x 15 cm., cloth. New York, D. Van Nostrand Company, Inc., 1928. Price, $4.50.

When the storage battery first became a commercial possibility, much was expected of it as an equalizer of the fluctuating loads carried by central stations. Factors of cost and upkeep at that time militated against its general adoption in that service. In the course of time, progress in the design of power-production equipment has rendered less insistent this means of improving the load factor. Forced draft by which steaming capacity is quickly increased, and the heavy overload capacity of engine and generator have done much to carry the load over the peaks. Further, where stations intercommunicate over large areas, the load factor is more favorable than in the isolated stations of an earlier day, and the

need of storage batteries in that service may be said to have been eliminated. To a restricted extent its use in that service survives, but in greater part, the industry has grown in meeting the demands of other applications, some of which are familiar to everyone, as for example, to the starting and lighting system of motor cars, electrically-propelled trucks and the now widely used electric lighting of steam railway cars, and many other equally important auxiliary functions.

The technique of storage battery engineering is of highly specialized character, and in order to successfully cope with its problems, a keen appreciation not alone of the electrochemical features of the subject but also of its constructive features is requisite. It is upon a practically useful plan of this sort that the present treatise is designed. First the general theory is taken up, then lead plates, factors influencing capacity and efficiency, the lead storage cell, its component parts and assembly, installation, operation and maintenance. This is followed by considerable space on the Edison nickle-iron-alkaline cell, and finally chapters on storage battery testing and on storage battery applications. The subject-matter throughout is adequately illustrated by half-tones and many illuminating diagrams of characteristics and performance. The inclusion of many practical details of manufacture, as precautions to be observed in lead-burning and types of construction are notable features. The work is thorough and exceedingly consistent in the treatment of its diversified contents.

LUCIEN E. PICOLET.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 290. Water-Pressure Distribution on a Seaplane Float, by F. L. Thompson. 15 pages, illustrations, plate, quarto. Washington, Government Printing Office, 1928. Price, ten cents.

The investigation reported herein was conducted by the Committee at the request of the Bureau of Aeronautics, Navy Department, for the purpose of determining the distribution and magnitude of water pressures likely to be experienced on seaplane hulls in service. It consisted of the development and construction of apparatus for recording water pressures lasting one one-hundredth second or longer and of flight tests to determine the water pressures on a UO-1 seaplane float under various conditions of taxying, taking off, and landing.

The apparatus developed was found to operate with satisfactory accuracy and is suitable for flight tests on other seaplanes.

The tests on the UO-1 showed that maximum pressures of about 6.5 pounds per square inch occur at the step for the full width of the float bottom. Proceeding forward from the step the maximum pressures decrease in magnitude uniformly toward the bow, and the region of highest pressures narrows toward the keel. Immediately abaft the step the maximum pressures are very small, but increase in magnitude toward the stern and there once reached a value of about 5 pounds per square inch.

THE MODERN CALORIMETER. By Walter P. White, Ph.D., Physicist in the Geophysical Laboratory of the Carnegie Institution of Washington. American Chemical Society Monograph Series No. 42. 194 pages, 16 illustrations, cloth 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $4.

According to the author this book was produced as an experiment. He has labored in no small measure to classify the various factors introducing sources of error; to treat in a thorough manner the methods involved in calculating these errors and to furnish a critical analysis of the applicability of these calculated errors to the desired precision in calorimetric measurements. A considerable portion of the book consists of the application of these various error calculations to operation of Joule's twin calorimeters, the ice, vacuum-walled, adiabatic, aneroid (fluidless) and last but not least the common type of calorimeter so well known to most of us.

An extensive dissertation upon the source and magnitude of possible errors comprises the first half of the book. This is followed by a discussion of methods in general and then by chapters on particular methods and apparatus in which the manipulation of several types of calorimeters are considered in more detail. The final chapter on "Application to Calorimeter Design and the Planning of Installations" is particularly valuable. In it are cited the required type of apparatus and necessary precautions corresponding to a desired degree of precision.

Primarily "The Modern Calorimeter" is for the perusal and study of those engaged in calorimetric measurements which are not of a haphazard or casual nature. It should prove to be a valuable aid in determining the absolute as well as relative precision obtained in calorimetric determinations. To anyone not versed in the technic of calorimetry this book will be laborious to read. Yet, those desiring a general idea of the scope of inventive genius and an unbiased evaluation of its own accomplishments in the field of calorimetry will do well to glance through this volume, even in a casual way.

The author's masterful treatment of the subject reveals an intimate, theoretical and working knowledge of the same and the opinion is expressed that such a pioneer attempt is to be greatly appreciated.

T. K. CLEVELAND.

NATIONAL ADVISORY COMMITTEE FOR AËRONAUTICS.

Report No. 308. Aircraft Accidents Method of Analysis. Report prepared by Special Committee on the Nomenclature, Subdivision, and Classification of Aircraft Accidents. 18 pages, illustrations, quarto. Washington, Government Printing Office, 1928, price, ten cents.

This report on a method of analysis of aircraft accidents has been prepared by a special committee on the nomenclature, subdivision, and classification of aircraft accidents organized by the National Advisory Committee for Aëronautics in response to a request dated February 18, 1928, from the air coördination committee consisting of the Assistant Secretaries for Aëronautics in the Departments of War, Navy, and Commerce. The work was undertaken in recognition of the difficulty of drawing correct conclusions from efforts to analyze and compare reports of aircraft accidents prepared by different organizations using different classifications and definitions. The air coördination committee's request was

made "in order that practices used may henceforth conform to a standard and be universally comparable." The purpose of the special committee therefore was to prepare a basis for the classification and comparison of aircraft accidents, both civil and military.

CHEMICAL ENGINEERING CATALOG. Thirteenth annual edition, 1160 pages, illustrated, quarto. New York, The Chemical Catalog Company, Inc., 1928. Prices adjusted to special conditions as indicated in the volume.

This publication has been noticed as it appeared in the issues of the Journal and it is necessary here only to record that the present edition maintains the character of the work as established in its earlier publications and constitutes a very valuable summary of the chemical engineering manufacturing in this country. The classified directory has been further enlarged and contains the listings of more than 2000 manufacturers. Its use to those engaged in purchasing the materials of chemical engineering is very great and the manner in which the publishers keep in touch with those who use the book is highly commendable. The information bureau maintained by the publishers for many years has been doing excellent service to its customers. More than 2400 books are listed in the technical and scientific books section. Information is also given concerning the American Chemical Society's Monographs. The book is printed in excellent form and very liberally illustrated. The present edition has a new feature in a Trade Name Index of nine pages. The individual pages give full and detailed information concerning the products of the firms using the space and these pages should always be consulted.

H. L.

PRACTICAL TELEVISION. By E. T. Larner, Engineering Department, General Post Office, London; Associate of the Institution of Electrical Engineers; Formerly Lecturer in Electrical Engineering at the London County Council (Hackney Institute), with a foreword by John L. Baird. 175 pages, illustrations, 22 x 14 cm., cloth. New York, D. Van Nostrand Company, Inc., 1928. Price, $3.75.

In the early nineties we had the first display of the "Kinetoscope" the forerunner of the modern cinema. Those who witnessed its performance through the binocular eye-pieces can testify to the excellence of the reproduction of the scenes displayed. Now, after an interval of thirty-five years, comes "television," the production of the image of a distant view transmitted electrically by wire or by wireless. Television is yet far from the practically usable state of the kinetoscope in its day, but its possibilities have been demonstrated, and the history of the cinema and other epoch-making inventions which have become commonplace bespeaks a successful evolution for television.

The striking achievement of the transmission of pictures by telegraph is something of an old story now. In that process, the time-lag of the selenium cell which it employed did not present the same obstacle as in television where instant response is essential; and the best promise of the latter appears to have come with the application of the modern photo-cell whose response to the action of light is many times more rapid. No extravagant claims are made for television by *bona fide* exponents of the art, but the goal of its promoters is to receive simultaneously sound and vision by radio. The activity in the effort to attain

that end is indicated by the recent announcement that nine radio stations are now broadcasting television on experimental schedules.

In the present volume, the author deals with the principles of television and the manner in which they have been utilized in the evolution of a practical moving-image transmitting apparatus. The history of the subject is outlined, and an account is given of the more modern researches in Europe and in the United States in which is included the work of Jenkins and Alexanderson. Considerable space is allotted to a discussion of the properties, construction and performance of the selenium and the modern photo-electric cell, but little more than passing mention is accorded the neon light. Considerable stress is laid upon the value of the cathode ray oscillograph tube for the successive illumination of different points of a fluorescent screen with no appreciable time-lag. The work with its ninety-seven excellent illustrations and diagrams constitutes a description of rare merit of what has already been done in the technique of television and what may be expected of it in the future.

LUCIEN E. PICOLET.

COLLECTION DE SUGGESTIONS SCIENTIFIQUES PUBLIÉE SOUS LA DIRECTION DE LÉON BRILLOUIN. Fascicule I. Quelques suggestions concernant la Matière et le Rayonnement par Th. Coppel, Georges Fournier et D. K. Yovanovitch. 46 pages, 22 x 14 cm., paper. Price, 4 francs 50. Fascicule II. Sur la Thíorie des Quanta de Lumiere par Al. Proca. 96 pages, 22 x 14 cm., paper. Price, 9 francs. Paris, Librairie Scientifique Albert Blanchard, 1928.

The present-day investigator in physical science has a much easier task in the search for precedent among the classics of the science than his predecessors of several decades anterior. Numerous monographs by authors of note which formerly were available only in periodical literature have become accessible by the publication of series on several divisions of physical science which cover a wide variety of topics. The present publishers have gone a step further in this movement by the issue of a unique series which cover what may be termed "classics of physical science in the making" rather than the work of already well-known authors. An extract of their foreword defines their object:

"Nearly all the daring ideas upon which the actualities of science are founded have seemed—the day they were first disclosed by some unknown investigator—fantastic, arbitrary, and even a bit absurd. The history of great discoveries offers the distressing spectacle of an extraordinary wastage of effort; what ideas, what suggestions scattered in inaccessible publications, forgotten or lost forever with their authors. What, for example, is more tragic than the lot of the notes of Carnot on the principle of equivalence, unpublished during his lifetime, lost, and a half century later found by chance after they had ceased to represent moie than historic interest? It is a fact that those ideas which have most profoundly influenced the progress of science have been relegated at the outset to the category of fantastic and absurd lucubrations. Why not then make profitable use of this lesson of history? Why not make a systematic search among ideas which appear eccentric and strange, at first, for suggestions of theories and applications of tomorrow? The present collection has for its very object to facilitate such research. For a given epoch, it aims to become the mirror of organized fantasies of scientists, a sort of library of new conceptions in which investigators

may seek inspiration and which the reader interested in matters of science will likewise consult with satisfaction."

Of the two initial contributions to the series, the first examines, with the freedom of thought permitted by an avowed speculative analysis, the fundamentals of the nature of matter and of radiation. Under this general title the authors review the modern conceptions of space, time and matter. In particular they dwell especially upon the quantification of space and of time, and further, upon a quantified universe. The idea of continuity, the Bohr principle of correspondence, β- and γ-rays, and the structure of the electron receives attention.

The second volume, on the theory of light quanta, aims to diminish some of the difficulties which are encountered in reconciling the two principal theories of optics, the wave theory, and that of light quanta. To that end, light quanta are considered in a medium devoid of all matter, the mechanism itself of the emission being disregarded. The structure of light quanta is examined in detail, its energy, and the general relation between this energy and the frequency are calculated. The phenomena of interference are considered and the manner in which the type of quantum adopted is applicable to an explanation of interference is discussed.

The rational and deductive character of these first volumes promise well for the value of the unique departure in scientific literature of the Collections de Suggestions Scientifiques.

L. E. P.

ELEMENTARY LABORATORY EXPERIMENTS IN ORGANIC CHEMISTRY. By R. Adams, Professor of Organic Chemistry in the University of Illinois, and J. R. Johnson, Ass't Professor of Organic Chemistry in Cornell University. 305 pages, illustrations, 8vo. New York, The Macmillan Company, 1928.

Though termed elementary experiments, most of the procedures described in this volume would have been regarded years ago as decidedly advanced, yet they are intended for first semester students, whether specializing in chemistry or merely seeking knowledge as accessory to professional study or practical application. Many interesting and important processes are described in full detail and a series of questions posed that cover the theoretical and some of the practical data concerning the procedures. Several procedures seem rather risky and while it is, of course, necessary to select from all fields in order to give the student a comprehensive training, yet less dangerous examples might have been culled out. However the work is presumed to be carried out under careful supervision and special cautions are given in the text for all the dangers.

The descriptions of the procedures are printed on sheets that can be easily detached and pasted in a note book, so that the book itself need not be kept at the operating table. Students are much too liable to keep their books where they work and thus get them stained and often seriously injured.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Théorie Ionique de l'Excitation des Tissus Vivants, par le Professuer Docteur P. Lasareff. 240 pages, illustrations, 8vo. Paris, Librairie Scientifique Albert Blanchard, 1928, price 40 francs.

Quelques Suggestions Concernant la Matière et le Rayonnement, par Th. Coppel, Georges Fournier, D. K. Yovanovitch. 46 pages, illustrations, 8vo. Paris, Librairie Scientifique Albert Blanchard, 1928, price 4.50 francs.

Sur la Theorie des Quanta de Lumière, par Al. Proca. 96 pages, illustrations, 8vo. Paris, Librairie Scientifique Albert Blanchard, 1928, price 9 francs.

Handbuch der Experimentalphysik, herausgegeben von W. Wien und F. Harms. Band 13, 2 Teil, Physik der Glühelektroden von Prof. Dr. W. Schottky und Dr. Ing. H. Rothe; Herstellung der Glühelektroden von Dr. Rer. Techn. H. Simon; Technische Elektronenröhren und ihre Verwendung von Dr. Ing. H. Rothe. 492 pages, illustrations, 8vo. Leipzig, Akademische Verlagsgesellschaft m.b.H. 1928, price 46 marks.

The Engineer, His Work and His Education, by Robert Lemuel Sackett, C.E. 196 pages, portrait, 8vo. Boston, Ginn and Company, 1928, price $1.40.

National Advisory Committee for Aëronautics. Thirteenth Annual Report, 1926. 510 pages, illustrations, tables, diagrams, quarto. Technical Notes, No. 297, Preliminary report on the Flat-top Lift Curve as a Factor in Control at Low Speed. 10 pages, diagrams, quarto. No. 298, The Determination of Several Spray Characteristics of a High-Speed Oil Engine Injection System with an Oscilloscope, by Chester W. Hicks and Charles S. Moore. 11 pages, plate, diagrams, quarto. Washington, Committee, 1928.

Great Britain Department of Scientific and Industrial Research. Radio Research Special Report No. 7. Wireless Observations During the Eclipse of the Sun, 29th June, 1927. 25 pages, plate, diagrams, 8vo. London, H. M. Stationery Office, price 1s. 3d.

Western Railways' Committee on Public Relations. Railroad Facts No. 6, A Yearbook of Railroad Information, 1928 Edition. 94 pages, illustrations, 8vo. Chicago, Committee, 1928.

Chemical Engineering Catalog. Thirteenth Annual Edition, 1928. 1107 pages, illustrations, quarto. New York, Chemical Catalog Company, Inc., price $10.00.

Electric Lines and Nets. Their Theory and Electrical Behavior, by A. E. Kennelly. 2d edition. 426 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, Inc., 1928, price $5.00.

Elementary Laboratory Experiments in Organic Chemistry, by Roger Adams and John R. Johnson. 304 pages, illustrations, 8vo. New York, Macmillan Company, 1928.

Heaviside's Electrical Circuit Theory, by Louis Cohen, Ph.D. First Edition. 169 pages, illustrations, 8vo. New York, McGraw-Hill Book Company, Inc., 1928, price $2.50.

Technical Books of 1927. A Selection. 28 pages, 16mo. Brooklyn, Pratt Institute Free Library, 1928.

CURRENT TOPICS.

An Ultra-Microscope of Small Dimensions. A. Turpain and R. Bony de Lavergne. (*Comptes Rendus*, June 11, 1928.) When a beam of rays of light falls on a transparent sphere parallel to a diameter, the size of the emerging beam depends upon the index of refraction of the material of the sphere. For a sphere filled with carbon bisulphide the diameter is only a third as great as for a sphere of water, while for a diamond the diameter is reduced to a point. By employing spheres of glass 2 or 3 mm. in diameter the authors succeeded in dispensing with the cumbrous illuminating devices used on ultra-microscopes so that the light from an electric lamp one cm. in diameter is sufficient. In addition high magnifications became possible along with other improvements of technique. "Under these conditions we were able to expose ultra-microscopic preparations to very strong magnetic fields and to convince ourselves that the particles in Brownian movement were not uninfluenced by the magnetic field provided it was brought to bear in a suitable way." G. F. S.

The Utilization of the Thermal Energy of the Sea. Georges Claude and P. Boucherot. (*Comptes Rendus*, June 4, 1928.) Claude, the distinguished French engineer, made public within the last few years a proposal for obtaining energy from tropical waters by taking advantage of the difference of temperatures that exist at different depths. Objections were raised to the feasibility of the project and to meet them the method has been tried out under conditions approaching those of practice and on a partly industrial scale.

Two tanks, each holding 100 cu. m., are at the same level and situated below the turbine to be operated. Both hold water taken from the Meuse River. In one the temperature is raised about 20° C. by steam or otherwise. The warm water is pumped up 9 m. to a chamber where it is freed of dissolved air. It then passes on at the same level to a space in which it evaporates under the greatly reduced pressure. The water cooled by evaporation flows down to the original lower level through a pipe and is thence discharged. The water vapor produced by the evaporation of a part of the warm water goes to drive a turbine and afterwards passes into a chamber where it is condensed by cold water from the second tank at low

level which also has been pumped up 9 m. and freed of gases. The turbine has a rotor one meter in diameter. Its normal capacity is 50 kw. but it is capable of giving 60 kw. To it a dynamo is coupled. In a test made May 19, 1928, the warm water cooled from 33° to 29.7° C., and the cool water rose from 12.8° to 16.2°. The turbine made 5600 r.p.m.; the dynamo developed 59.4 kw., of which 11 kw. were used for pumping and 7 kw. in getting rid of the dissolved air. Thus 41.7 kw. were left available. This is 69 per cent. of the output. This shows that the auxiliary operations do not absorb the entire power of the dynamo as was objected.

At the end of the presentation of the paper H. LeChatelier said: "If the final installation in Cuba is to become a reality, as everything now seems to indicate, this day of June 1 will remain historic in the archives of industry. This is the first time that an actual steam machine has been seen running with a difference of temperature of 10° only. All the experts regarded the thing as impossible.

"For a long time people have been concerned with the future of civilization on the earth at the time when coal mines shall be exhausted. It was thought that we should end by discovering some other process for utilizing solar energy, but trials made with solar engines or with turbines operated by the tides required the investment of so much capital that finally such solutions came to be regarded as economically impossible. The heat accumulated in sea water, while it is not as concentrated as that stored up by vegetable life in the Coal Period, does, however, present infinitely more advantages than all other previous solutions of the problem." He spoke of the success attained in maintaining the vacuum in the machine, of the ease of starting it or slowing it down. There remains the difficult task of putting in place the long pipe that is to bring up from the depths of the sea the cold water for condensation.

In addition to his engineering work Claude was this spring a candidate for election to the Chamber of Deputies in the second district of the department of Seine-et-Marne (Fontainebleu). His campaign was conducted in a unique way. *Le Matin* of April 12 gave an account of his methods in an article written by Stéphane Lauzanne. The place was a dance hall on the edge of the Forest of Fontainebleu. There were no benches but boxes had been brought in to serve as seats, which were chiefly occupied by women. These formed a large part of the audience though they do not vote in France. "A door opens. A man appears, astonishingly young under his curly gray hair, and the audience stiffens with respect mingled with curiosity. George Claude begins his address. 'Ladies and gentlemen, by science life can be directed toward prosperity. I shall therefore talk to you about science. It is a

thing that I know. For once you are going to hear a candidate on something that he knows.' First he spoke about liquid air in the production of which he has played so large a part. He then showed a series of experiments. His five hundred auditors broke into applause. He appealed to his audience to rely more on science and less on politics for the return of prosperity to their country. 'Science will aid to bring peace also, for she will make France stronger. I have a horror of war. I believe there are Germans who have the same horror.' He was heckled and flung back 'That doesn't suit you what I said then? Very well. Don't vote for me. You know I don't care a hang about being elected.'" In the first election he received 9338 votes against 9183 for his nearest opponent. It was necessary to ballot again as no candidate received a majority of all votes cast. At the second election he received only 6355 votes. The man who was next to him at the first election was elected as he received 6614 votes. G. F. S.

New Precision in Cosmic Ray Measurements; Yielding Extension of Spectrum and Indications of Bands. R. A. MILLIKAN AND G. H. CAMERON. (*Phys. Rev.*, June, 1928.) Up to the present time there has been only the most general agreement in the measurements made on cosmic rays by different observers. For example, at high altitudes Millikan and Bowen found a total discharge for an electroscope that was only one-fourth of that calculated from the curves of Kohlhoerster and Hess, and for Pikes Peak Millikan got a rate of production of ions seven times as large as that found by Swann for the same mountain. "Such differences are quite like those found, for example, in the early determinations of e/m which showed fluctuations of 100 per cent., but they cannot long be permitted." The authors, therefore, turned from the study of the variations of cosmic rays in relation to altitude, direction, geographical position and penetration to the development of better measuring instruments. They have produced an electroscope of spherical shape especially designed for use under water. Its walls are of steel .6 mm. thick so that its sensitiveness can be greatly enhanced by increasing the atmospheric pressure within it. Furthermore its capacity can be determined with high accuracy.

With a pressure of eight atmospheres within it the electroscope was about eight times as sensitive as the instrument previously used under water. It was used for a new series of studies of the penetration of cosmic rays into mountain lakes, Arrowhead Lake, elevation 5100 ft., depth 140 ft. and Gem Lake, elevation 9080 ft. and depth 225 ft. Though they differ so much in elevation and though one lake is 250 miles north of the other "as in the case of all

our former under-water work, when the rates of discharge are plotted against depth in equivalent meters of water beneath the top surface of the atmosphere, *the readings all fall upon a smooth ionization-depth curve.*" The curve indicates that the precision is 10 times as great as that of their previous submarine instrument, and hence important conclusions can be deduced from a consideration of the curve. (In what follows depth is reckoned in equivalent meters of water below the upper surface of the earth's atmosphere.) The rate of production of ions goes on diminishing as the electroscope is lowered into the water until a depth of 58 m. is reached. In previous experiments the decrease ceased at 25 m. "This means at once that our increased sensibility has brought to light very much harder rays than we had observed before." Again, the absorption coefficient of water for cosmic rays at a depth of 10 m. is .20 and a meter lower it has dropped to .11. This sudden change "at a depth of about 11 m. means that at that point a band of long wave-length, or of relatively large absorption coefficient, is dropping out and one of much shorter wave-length is left to cause the bulk of the ionization. The present measurements at least furnish indications that the cosmic rays consist chiefly of three bands for which the mean absorption coefficients are approximately 0.35, 0.08 and 0.04. Our shortest wave-length is now 0.00008 A, and the equivalent generating potential approximately 150,000,000 volts."

A calculation is made of the amount of energy brought by the cosmic rays to the earth. It is 3.02×10^{-3} ergs per sec. per sq. cm. This is about one-tenth of the influx of energy due to starlight.

G. F. S.

An Attempt to Add an Electron to the Nucleus of an Atom. W. D. HARKINS AND W. B. KAY. (*Phys. Rev.*, June, 1928.) Theory indicates that an electron is attracted by the nucleus of an atom. It may be that an ion can be driven into an atom with sufficient velocity to make it come within the range of the attraction of the nucleus. Electrons with an energy of 145,000 volts and a velocity of 1.9×10^9 cm./sec. were made to impinge on a surface of mercury that formed the anti-cathode in an X-ray tube. Mercury was selected because it can be separated almost completely from gold, the next lower element, and because a very small amount of gold can be detected in a large quantity of mercury. Should an atom of mercury receive an electron into its nucleus it should be thereby converted into an atom of gold. Though the stream of electrons bombarded the mercury for as much as 81 hours no trace whatever of gold was found. Had every ion lodged in a nucleus gold by the gram would have resulted. Certainly not one ion in a billion was

effective, though a billionth of a gram of gold could have been detected. G. F. S.

The Vibration of Bells. A. T. JONES. (*Phys. Rev.*, June, 1928.) This paper is the result of a study of the 10 bells of the Harkness Memorial Chime at Yale University. Little is known about the vibrations of bells. The partial tones of the same bell generally have inharmonious relations to one another, and the series of relative frequencies of the partials of one bell will not agree with the same series for another even if both bells came from the same maker. There is a concensus of opinion of some value that the first 7 partials should have frequencies with the ratios 1 : 2 : 2.4 : 3 : 4 : 5 : 6. It is to be noticed that all the numbers are integers except the third which is sometimes given as 2.5 instead of 2.4. The bells of the Harkness Chime had partials agreeing closely in frequency with the relations just given. The ratios about to be given are for the first 7 partials the averages of 10 bells but for the 8th, 9th and 10th for only 7 bells. The ratios are 1 : 2 : 2.4 : 2.98 : 4 : 5.12 : 5.92 : 6.56 : 7.6 : 8.12. For the Dorothea Carlile Chime at Smith College the same set of partials, except that the 8th is omitted, have these ratios,— 1 : 1.58 : 2.05 : 2.95 : 3.45 : 4.72 : 5.17 : ( ) : 6.5 : 7.02. The graphic representation of the sounds from the Yale bells was obtained by using a microphone, amplifier and oscillograph with photographic registration. When the bell is struck there is a period of irregular motion lasting from .01 to .03 sec. This is succeeded by a considerable increase in amplitude and the arrival of a more regular type of vibration. In all the films good enough for analysis the 5th partial had a larger amplitude than any other, just after the end of the irregular motion. Records taken 3 sec. after bells were struck showed that large bells still had several important partials, while small bells possessed only one of any amplitude. G. F. S.

Michelson's Experiment Carried out in a Balloon and also on the Ground. A. PICCARD AND E. STAHEL. (*Jour. de Phys.*, February, 1928.) Dayton C. Miller, repeating Michelson's experiment on the drift of the ether past the earth, announced the existence on Mount Wilson of an ether wind of 10 km. per sec. This result is of fundamental importance because, if it is true, the very foundations of the Theory of Relativity are made to totter. It is consequently well that the experiment should be made under varying conditions and with different apparatus. The authors who are Belgians devised an apparatus much smaller that that used by Miller, yet having, according to their claims, greater accuracy, though in the

balloon temperature disturbances were considerable. Measurements were conducted at Brussels, in a balloon and on Rigi, in Switzerland. In no case do their results confirm those of Miller. It is, however, to be remembered that Professor Miller has had decades of experience in the conduct of this particular experiment, in which regard he has great advantage in respect to those who are criticizing his work. G. F. S.

The Existence of Intermetallic Compounds in the Vapor State. The Spectra of the Alkali Metals, and of their Alloys with Each Other. J. M. WALTER AND S. BARRATT. (*Proc. Royal Soc.*, A 782.) "It has been uncertain until recently, whether any of the many intermetallic compounds which have been established in liquid and solid alloys can persist into the vapor state, or whether they invariably dissociate into mere mixtures of the individual metal vapors. Volatile compounds have occasionally been suspected (*e.g.*, between magnesium and zinc) on account of the deposition of typical crystals of compounds during the distillation of an alloy of the two metals, but such evidence is so indirect that it carries little weight. The most promising way of approaching this question is by a study of the absorption spectra of mixtures of metallic vapors. The metals that are known to possess a measurable proportion of diatomic or polyatomic molecules in the vapor state invariably indicate this property by the appearance of bands in their absorption spectra. In fact, since it has been accepted that band spectra cannot originate from single atoms, the observation of such bands has become the most delicate test for the existence of association in the vapors." As a result of molecular weight determinations it has been held that the vapors of alkali metals are altogether monatomic, but this can no longer be maintained since these vapors show band spectra.

It has previously been shown that the mixed vapor of sodium and potassium has two band spectra and the conclusion has been drawn that there is an intermetallic compound existing in the state of vapor. Later by the same evidence it is clear that magnesium forms a volatile compound with each of the alkali metals. "In establishing the existence of an intermetallic compound by this method, the assumption is made that the spectrum of a mixture of two metals is purely additive unless a new type of molecule (i.e., of a compound) is formed, which is peculiar to the mixture." Before searching for band spectra in mixtures of metallic vapors the spectra of the several alkali metals were carefully examined. New bands were discovered for rubidium and cæsium. Then the spectra of each of the ten pairs of metals that can be grouped from lithium,

sodium, potassium, cæsium and rubidium were inspected for bands. No bands were attributable to lithium-sodium but each of these presents so many bands that the band of the compound may be hidden. All the other nine pairs showed bands, sodium-potassium having the most extensive. In general the bands lie close to the lines of the principal series of the two united atoms, but this is not true when lithium is one of the metals.

What fractional part of the total vapor is in the form of intermetallic compounds? Carelli and Pringsheim found that at 727° there are 2 per cent. as many diatomic atoms of potassium vapor as monatomic ones. For the same quantity Ditchburn obtained .9 per cent. Mitchell, by Victor Meyer's vapor density method got 5 per cent. The authors hold that at the boiling point of the metals these molecules containing one atom of each of the two constituent atoms make up one or two per cent. of the total vapor.

G. F. S.

† Died February 7, 1928.

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PRESENT AND PROPOSED ACTIVITIES OF THE FRANKLIN INSTITUTE *

A REPORT TO THE MEMBERSHIP BY

HOWARD McCLENAHAN, E.E., M.S., LL.D.

Secretary of the Institute.

THE last few years have been years of vigorous life and activity in the Institute, and have witnessed growth and development which promise much for greater usefulness of the Institute to the city, and for enhanced reputation for this old society. Unfortunately, some of our members report that, to their regret, they have not been cognizant of these facts; they have expressed the wish that they might have an opportunity to learn in person of the plans and purposes about which now they read only in the papers. Apparently we are not good advertisers, and have been so much occupied with the plans themselves that we have had little time and energy to tell about them.

In preparing the programme of meetings and lectures for the year, the Secretary felt that the lecture season could not be inaugurated better than by a comprehensive report concerning the state of the Institute to the members of it. Thereby should come sympathetic understanding, warmer interest and more active support. So he has given himself the privilege, which is a pleasure, of addressing you tonight

* Presented at the Stated Meeting of the Institute held Wednesday, October 17, 1928.

on the "Present and Proposed Activities of The Franklin Institute." He will find satisfaction and encouragement if the activities of the Institute, and especially our new branches of work, described in this report to the membership, shall meet with your approval.

Laments have been uttered by some of our older members that our meetings have lost something of interest through their increased efficiency and the opinion has been expressed that they would regain their former quality if there could be more genuine discussion. Tonight offers the opportunity for such a revival. You are sincerely invited—"if you see a head" which you don't like, to "hit it." It is genuinely wished that if you do not approve of what is being done or is being planned, you will say what you think now, or at some early opportunity. You will observe that we do not use the ministerial admonition, "Let him now speak or else hereafter forever hold his peace."

It has been, I believe, a long-time practice of the Institute to honor the speaker of the evening by having him meet at dinner, in advance of his talk, some of his Philadelphia friends, some of the outstanding figures of Philadelphia life, and a few of the members of the Institute. There seemed to be no need for such a dinner tonight in honor of the speaker. A much more agreeable motive was suggested, that the dinner of this evening be made one of honor to all those members whose membership exceeded a certain minimum, but large, number of years. The suggestion was eagerly accepted. The problem then was to determine this *minimum* period of membership. Forty years was adopted tentatively for this number, and a census of our membership was taken to find how many guests could be invited under this limitation. To our great satisfaction, we found that no less than seventy-one members "had joined the Institute more than forty years ago." A dinner for such a number was more than we ventured to plan for. Consequently, we raised the limit to forty-five years and took a new census. It showed that of our membership, 31 had been members for forty-five or more years, so invitations were sent to all of these 31. Eight gave us the pleasure of attending the dinner in their honor, and have shown their interest by coming to this meeting tonight. The

speaker feels much complimented by the presence of these honored and youthful fathers of the Institute. Our presiding officer is one of the short-time members. He joined the Institute only a little more than forty-seven years ago and has been successfully active in all of the affairs of the Institute from that time to the present. One of the thirty-one has been uninterruptedly a member of The Franklin Institute for more than sixty-two years. Surely these figures which have been quoted constitute a superb record of loyal support.

I cannot forbear from referring to the saddest incident in the affairs of the Institute during the last year. One year ago we were meeting under the chairmanship of our honored President, Dr. W. C. L. Eglin. He appeared to be at the peak of his acknowledged powers—able, forceful, considerate, courageous. We naturally looked forward to years of successful effort with his powerful aid and encouragement. On February 7, last, he was taken from us by death; the Institute was lastingly bereaved by the loss of this man for whom we knew great respect, cordial admiration and warm affection. We mourn the taking off of a strong man and a gifted leader.

It is sometimes a good thing to be reminded of things. Tonight I wish to recall to you something that you all know already, the origin and the purposes of The Franklin Institute.

In 1823 and 1824, so the records tell us, two young men—W. H. Keating, subsequently Professor of Chemistry in the University of Pennsylvania, and Samuel Vaughan Merrick, later the first President of the Pennsylvania Railroad, were desirous of learning something of the applications of fundamental science in business and industry. They applied for membership in a society then existing and in which they believed they could readily learn what they wished to know. To their great indignation, probably to their surprise, they were refused admission. Then they did a sensible thing—they took counsel together and thought over the whole situation. They were young men of high standing, they were of the socially elect. Said they, "if *we* cannot find the opportunity to learn what we wish to know, what chance has the poor boy who has no friends? We will organize a society open to all men and women of intelligence, character and ambition who are interested in science."

This was the inception of The Franklin Institute. It was organized as a democracy in science whose purpose was "the promotion of the mechanic arts." It has remained true to that purpose to this day. With one exception, the activities assigned by the Founders are carried on today with vigor.

They started a library in the physical sciences and, after a few years began to collect patent literature. Today our library is the best library in the physical sciences in or about Philadelphia, and possesses the only great collection of patent literature to be found between New York and Washington. We are the official depository for the governments of the United States of America and Great Britain, and have their complete files, and have much patent literature from other foreign governments.

"The Fathers" started a journal for dissemination of scientific knowledge. That Journal of The Franklin Institute has appeared twelve times a year without interruption from 1825 to the present time. I know of no journal or magazine of its type which has anything like a comparable record of age and continuity. Our Journal has become an outstanding journal of physical science. Thanks to the publications of scientific papers from our research laboratories, the laboratories of the Bartol Research Foundation, the Journal will not fail to deserve an increasingly high reputation.

From the outset the authorities of the Institute have arranged for lectures before our members and their friends by the leading men of the world in their several fields of study. Much stimulation and much encouragement have resulted for the scientific workers of the city. A glance at the lecture programme which has been sent to you will convince you that a high standard of excellence has been maintained for these talks. Many of the scientific marvels of the world have been first publicly described in the Hall of The Franklin Institute. This practice has been continued. The brilliant Directory of Research of the Eastman Kodak Company has asked if he may present the first public description of the new method devised by the Eastman Kodak Company for taking motion pictures in the natural colors at a meeting of the Institute. This lecture and demonstration will be offered to us in this Hall next week.

During all of its history, the Institute has been greatly interested in inventions and has desired to encourage and to aid inventors. For the accomplishment of these purposes, the Institute now has eight medals which are awarded for discovery or invention in different fields only after careful investigation by committees of experts appointed from a group of sixty men who constitute our Committee on Science and the Arts. All of the medals which are awarded during the Institute year are now presented to their recipients on out last meeting day of the year in May, which is known as Medal Day. It seems to have become one of the interesting scientific events of Philadelphia.

These are the activities of the Institute which were initiated by our forbears which are carried on successfully, we hope, today. We are trying in every way to strengthen these lines of work so that they shall be of more value to our members and to Philadelphia.

One other activity which was started almost at the organization of the new society has been discontinued after ninety-nine years. Schools were conducted in the Institute in various branches of pure and applied science, physics, chemistry, mathematics, machine design, engineering drawing, architecture. Many of the leaders of Philadelphia life had their training in the schools held within these walls. The great Central High School of Philadelphia had its inception here and, for years, was known as the Franklin Institute High School.

But other institutions, of which Philadelphia is properly proud, came in and carried on the work admirably and sufficiently, so that The Franklin Institute could devote itself and its limited funds to work which others were not doing at all. The schools of the Institute were discontinued, wisely, I am sure, yet with regret, I feel equally sure.

We have not been content to carry on *only* along the old lines. We desire to open new roads to learning for our members and for the citizens of Philadelphia, especially for the children in the schools of the city. And we have opened a new agency for the advancement of human knowledge and have created a great tool to aid in man's conquest and domination of Nature—the laboratories of the Bartol Research Foundation.

May I take some of your time in order to describe somewhat in detail these new features of the work done here?

In the spring of 1926 our president, Dr. Eglin, suggested that a desirable addition for us would be a set of Christmas Week lectures for young people, similar to those which were first delivered by the great Faraday in the Royal Institution of Great Britain nearly a century ago and which have been given year after year, to the present time. This suggestion was adopted by the Board of Managers and the first course of lectures was arranged for. Those lectures were delivered by Professor R. W. Wood of Johns Hopkins University in the Christmas Week of 1926. An enthusiastic crowd of young people attended and were greatly rewarded by the absorbingly interesting lectures on "Recreations with Radiations" which they heard. The speaker cannot think of a more brilliant, a more attention-compelling, group of lectures than Professor Wood gave.

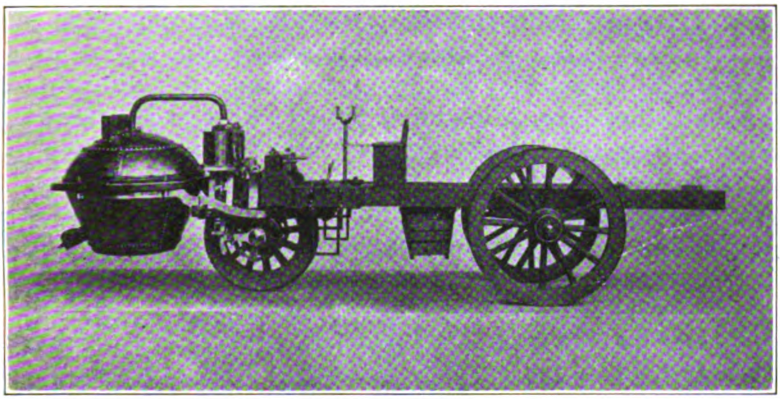
At the close of the course Mrs. James Mapes Dodge established the James Mapes Dodge Lecture Foundation as a memorial to her late husband, James Mapes Dodge, one of America's great inventors, the holder of some hundred and fifty letters patent from the United States alone, a long time member of The Franklin Institute, a member of its Board of Managers for years, a vice-president of the Institute at the time of his death—a congenial companion and a loving friend of young people. By means of this fine Foundation we are assured of our ability to carry on these Christmas Week Lectures for Young People at an almost nominal charge to the auditors and without drain upon the other resources of the Institute. In London, the Juvenile Lectures of the Royal Institution are attended by capacity audiences, including many of the leaders of thought and science of the kingdom. They are regarded as events of social importance and have been attended by the King and the Royal Family.

In 1927 our lecturer was Professor Wilder D. Bancroft of Cornell University, while for the lecture course of the approaching Christmas period we have been fortunate to secure Professor A. S. Eve of McGill University, Montreal, whose lectures will be on the topics, "Things that Spin," "Things that Swing," "Things that Wave." We are guaranteed a

wealth of striking experiments through all of these lectures and, I believe, an interesting trio of talks.

In 1918 Mr. Henry W. Bartol, a leader of industry in Philadelphia, bequeathed to The Franklin Institute his residual estate for the establishment and operation of a laboratory for research in the physical sciences and for the study and solution of problems of a scientific character.

FIG. 1.



The World's First Automobile.

You will see what freedom of action this gives to those directing the workers in the laboratory. After four years of litigation a settlement was arrived at by which the Institute received a sum which now amounts to one million, eight hundred thousand dollars, and which will eventually amount to at least two millions, four hundred thousand dollars, as endowment for the Bartol Laboratories.

During the years 1922–1925, four dwellings on the property of the Institute on North Nineteenth Street were remodeled and equipped for use as a physical laboratory. In the autumn of 1925 active research work was begun, the first Bartol Research Fellow, Dr. Arthur Bramley, was appointed, and an arrangement was entered into with Dr. Swann of Yale and Professor Adams of Princeton, to serve as an advisory committee to supervise research; a promising start was made

towards the fulfillment of the purposes of Mr. Bartol's handsome bequest.

In September, 1927, Dr. W. F. G. Swann, formerly Professor of Physics at the University of Minnesota, at Chicago University and at Yale University, at which place he was head of the Department of Physics, came to us as Director of the Bartol Research Foundation, in charge of the scientific work of the laboratories.

We have added other Fellows, all of high attainment and outstanding ability, who have come to us from Princeton, Yale, Harvard, Mt. Holyoke, Purdue, Virginia, until Dr. Swann is the head, the guide, philosopher and friend, of an enthusiastic scientific family, consisting, in addition to himself as Director, of eight or nine Fellows, a skilled glass-blower, three trained machinists, and the necessary clerical and other assistants. Dr. Swann has made of the Bartol Laboratories a hot-spot radiating scientific enthusiasm and sending out an ever-increasing stream of valuable contributions to scientific knowledge, accounts of work done and knowledge gained at our laboratories.

This work has gone on in spite of handicaps of a physical character. The houses on Nineteenth Street were not raised to be physical laboratories. They have about the physical steadiness of a teetering mosquito in a gale of wind. Every time an overladen truck dashes south through Nineteenth Street, or a P.R.T. trolley roars by, every piece of delicate apparatus indulges in a spell of St. Vitus' dance, and all measurements must be suspended. Because of these conditions the laboratories on Nineteenth Street are to be abandoned and the work now carried on in them is to be shifted to the Bartol Research Laboratories of The Franklin Institute now under construction on the campus of Swarthmore College. An agreement has been made with that College by which it leases to us a fine piece of ground for a nominal rental, on which we are building what promises to be an excellent laboratory. No other formal association is entered into. But the advantages are reciprocal. We obtain a fine site for our building in the atmosphere of a lovely, thriving college, with the cultural associations which go with life in such a community. Swarthmore gains the stimulating effect upon

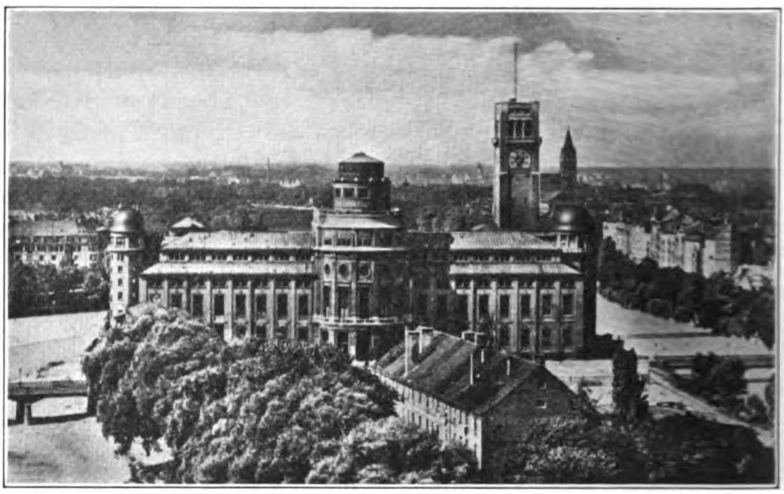
its students of the presence of a group of able young people carrying on researches of fundamental importance, and, perhaps also, the opportunity for some of its best students to assist in such researches. We hope to occupy the new laboratory about March first, after which we may confidently expect results which will bring reputation and satisfaction to Dr. Swann and his fellow-workers and honor to The Franklin Institute.

You will have seen in the daily papers during the last fifteen months, and especially since last May, frequent reference to the scientific museum of The Franklin Institute, and to an agreement between that Institute and the Benjamin Franklin Memorial, Inc., sponsored by The Poor Richard Club, by which such a great museum as is dreamed of, is to be made a possibility. The journalists of Philadelphia seem to have sensed accurately the importance of the project in hand and to have appreciated the value and importance to Philadelphia, and especially to the young folks of high school grade of this great new institution which we are eager to give to this city. These journalists have given us highly intelligent approval and support, without exception, and are giving us, and will give us, invaluable aid.

The Poor Richard Club, for a long time has had a great altruistic desire to do honor to its patron, Benjamin Franklin—that much adjectivized American. The Franklin Institute of the State of Pennsylvania has long sought to enlarge its contributions to the welfare of the youth of the country. During the last two years the Poor Richard Club has given much thought and study to the question of how they could best accomplish their purpose of doing honor to Franklin. That Club has organized the Benjamin Franklin Memorial, Inc., as its agency for fulfilling its desires. Under the leadership of Mr. Cyrus H. K. Curtis, and including in its membership the leaders of Philadelphia in finance, in engineering, in inventive industry, in good citizenship, the Benjamin Franklin Memorial, Inc., sponsored by the Poor Richard Club, has entered into an agreement with The Franklin Institute, in accordance with which they are to coöperate in bringing about the erection and equipment of a great, beautifying structure in a central section of the city,

preferably on the Parkway, which shall include a monumental architectural memorial to Benjamin Franklin, a collection portraying the graphic arts as they were when Franklin was an active printer in the Quaker City, and showing also their development to the present time, a great scientific and technological museum which shall rival the scientific museums of Europe, and the auditorium, library, offices and other

FIG. 2.



Deutsches Museum—Munich.

rooms demanded by the activities of The Franklin Institute.

The Benjamin Franklin Memorial, Inc., agrees to try to raise sufficient money, about four to four and a half million dollars, to erect the initial structure and to aid in its equipment. The Institute agrees to make available for endowment purposes that part of its fixed endowment which can be properly allocated to this project. That sum is now determined to be two millions, six hundred thousand dollars. The Institute will add to this endowment when possible to do so, and will aid in procuring funds from friends to whom an appeal may be effective because of their interest in The Franklin Institute rather than in the City of Philadelphia. The Institute will operate and administer the whole splendid structure for the benefit of the City of Philadelphia.

The ambition of the Benjamin Franklin Memorial, Inc., and of its parent organization, the Poor Richard Club, is solely to build what they regard as a proper memorial to Benjamin Franklin. They, however, recognize as clearly as any one, that Franklin would be the first to object to any memorial which was only ornamental and did not have as a large element in its character a quality of usefulness and applicability to ordinary affairs. They have therefore combined with The Franklin Institute to erect a great structure

FIG. 3.

La Conservatoire des Arts et Metiers—Paris.

which shall not only be a beautiful architectural memorial to Franklin, but shall also house a great new educational institution which shall carry on the work in which Benjamin Franklin was an epoch-making leader, and shall vitalize the teaching of physical science in this community. It is a pleasure to take this opportunity to pay sincere tribute to the Poor Richard Club and the Benjamin Franklin Memorial, Inc., for their altruism and public spirit as displayed in their present undertaking.

May we not justifiably feel that the whole structure with its living activities will be a superb memorial to that sage and

philosopher, Benjamin Franklin? The purpose and the work of the Institute have always been, perhaps, the most effective exemplification of the scientific principles of Franklin in that they have made a knowledge of science available to all men without regard to caste or state. In its new and enlarged sphere, which is to be made possible by the association of the Institute and the Benjamin Franklin Memorial, Inc., of the Poor Richard Club, the Institute will have as its fixed purpose to administer the Museum and Memorial so as to make it a worthy tribute to Franklin, a scientific shrine to which men will come for inspiration and learning, a noble addition to the architectural beauty of the city Franklin loved, and a lasting source of satisfaction to those who have labored for its accomplishment.

Because of our belief in the value to the city of our plan we have asked the city authorities to lease to us a suitable site for the erection and maintenance of this institution. If you believe in us and in our schemes, give us your support and your vocal approval.

We desire so greatly to have you understand what it is we are trying to build and why it is such an important thing for a city of two million people, that I ask you to bear with me while I outline our project and set forth our plans.

In the first place, there has come about a great change, a happy change, in our conception of the purpose and the character of a museum. Not so long since, a museum was merely a depository for the collections of a man with an acquisitive sense. All too often, it was only a junk heap, without much of designed arrangement, a more or less great collection of 'firsts' in the special field of interest. Only originals were tolerated—and copies, however perfect, were taboo. And all too often, the museum connoted death and inaction and lack of stimulus. Fortunately that conception of a museum has gone by the board. It is no longer primarily a home for collections. It is regarded as a great agency for education, for training, for enlightenment—and should be a dynamic adjunct to the teaching facilities of the community. These statements should be just as true—or more nearly wholly true—of a scientific museum as of an art museum, or of a commercial museum, or an historical museum. As a fact,

the accomplishments of science lend themselves with especial readiness to successful, inspiring use in such an institution as we have in mind.

You have seen in the great and beautiful Philadelphia Art Museum, at the top of the Parkway, a fine example of the possibilities of this new conception of a museum, as applied to a collection of works of art. The fine arts are there looked

FIG. 4.

Das Technische Museum—Vienna.

upon as unitary. They are to be grasped as an inter-related whole, and not as a mere congeries of more or less disparate units. Painting and statuary and architecture, coloring and illumination are to be combined into one beautiful whole. And through all, there runs the purposeful display of the development, the evolution, of the artistic organism.

"Period rooms" are used to provide the natural setting for portraits and landscapes. The style of the costume is to be harmonious with the architecture of the corresponding period,

and so growth from primitive state to sophistication will become readily evident.

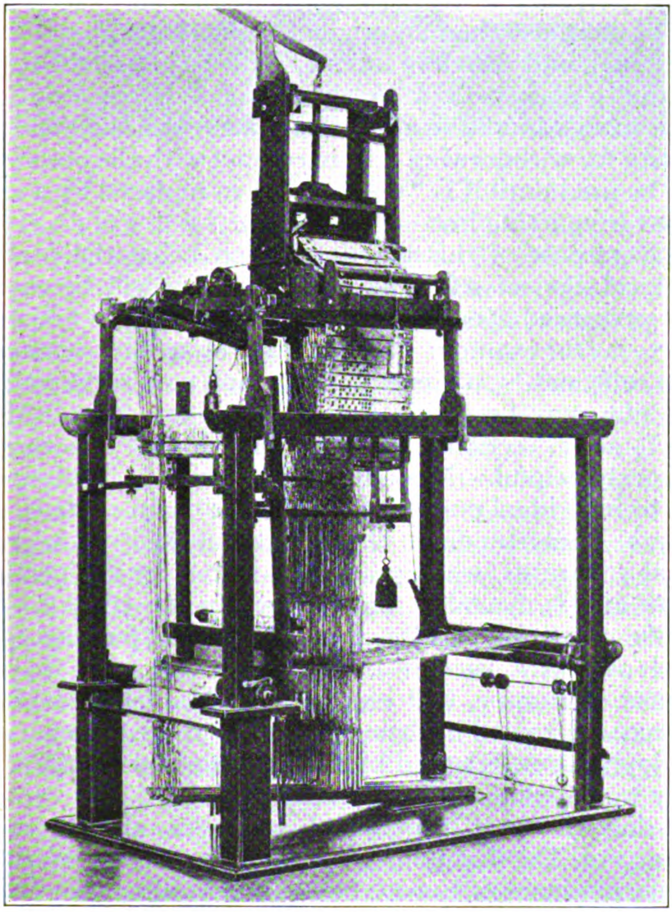
Exactly the same purpose underlies the establishment which we are planning. It shall be a place where the *principles* of science are emphasized, where the scientific fundamentals are displayed as they find application in industry, and where the growth of manufacturing and engineering processes are portrayed with the utmost possible clarity. The emphasis must always be upon the idea of development. The purpose shall be to show how the present, perhaps very complex, method has come about, what has been the scientific evolution which has taken place. In such an institution, the acquisition of detailed knowledge *and* the understanding of the whole process will of necessity go together.

There has come about another and vital change. In the old type of museum, the object most frequently seen was the "Please do not touch" sign. That sign in the modern science museums is almost as rare as some of the exhibits. The visitor is expected, even urged, to handle, to operate, the exhibits. When, in order to prevent injury to the uninitiated, a "Do not touch" sign has to be displayed, it is accompanied by another stating that the machine or device or process will be operated by the attendant, upon request. The visitor is at liberty to repeat his observations just as often as he finds it desirable to do so. And, just as far as it is possible to do so, every exhibit is to be made active, be made "to run." The "wheels go round" in the case of a machine, the chemical reactions of the manufacturing processes are carried out, the metals are deposited in any example of electrolysis, in every case there is a display of life and reality. The combination of these two abilities, the ability to touch, to handle, the exhibits, and the ability to "make them go," is the characteristic of the modern museum and is that feature which insures their greatest usefulness.

In the institutions of the older type, the aim was always to get originals. This fact was inherent in the very nature of the institution. Now it is true that the possession of at least a few pieces of apparatus with which some fundamental discoveries were made lends a tang, an atmosphere, which can be obtained in no other way. No electrical engineer, or

physicist, can fail to have a thrill when he stands in the Deutsches Museum in Munich, before the apparatus with which Heinrich Hertz laid the foundation for the development

FIG. 5.



Original Jacquard Loom.

of wireless communications. What must be the feeling of a textile man when he is in the presence of the original Jacquard loom in La Conservatoire des Arts et Metiers of Paris? And how must a member of The Franklin Institute thrill when he

can touch the original electrical machine of Franklin, or the coils with which Faraday made his immortal discovery?

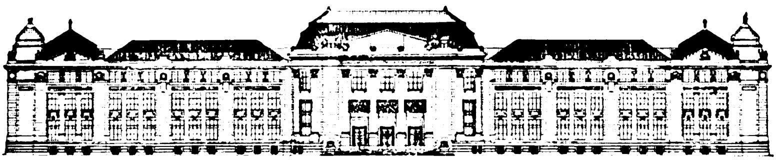
The originals are like salt on food—they add a flavor and give distinction. But, as in the case of salt, a little goes a long way. A few great originals are enough. And, indeed, for the purposes of the modern museum, an exact copy is often of more use than an original. The latter, because it *is* the original, and therefore unique, must be guarded and often kept under glass or lock for protection. If one exact copy can be made, another can also be made—so that there is no necessity for withdrawing it from contact with the observers—it can be used until it is "used up," then replaced by a second without irreparable loss.

The purpose of this new institution being the portrayal and elucidation of scientific principles, use will be made of every recognized agency for successful teaching. Sometimes a chart—as for example, in a portrayal of an electric circuit—will be sufficient. At times a photograph may serve well, or a movie film may be required to show all the steps. Models made to scale, sectioned to show the internal structure, are enormously helpful. Models, on an enlarged scale of separate parts, or individual portions of the whole chain of steps, often facilitate understanding. Diagrams, copies, photographs, original apparatus, whatever is best suited for the particular purpose and is available, will be used in the effort to make scientific principles vividly clear. That this purpose can be carried out with success is shown in the great scientific museums of Europe, and especially of Munich and Vienna. The success attained in their purpose by these museums, and the enjoyment experienced by the visitors to them, show how greatly worth while such institutions can be.

During the past summer, I was sent abroad, as the Secretary of The Franklin Institute, in order to study the scientific museums of Europe before undertaking the planning of the museum of the Institute in Philadelphia. I visited museums in Paris, Munich, Vienna, Budapest, Jena, Cologne and London, in the expectation of obtaining information and ideas which would be of value in developing our own plans. This expectation was not disappointed. I have come back with reports, drawings, criticisms, suggestions concerning the

European institutions, and with an exalted conception of what such a museum should be, which will be of the greatest value in putting our plans into execution.

FIG. 6.



Front of Technische Museum.

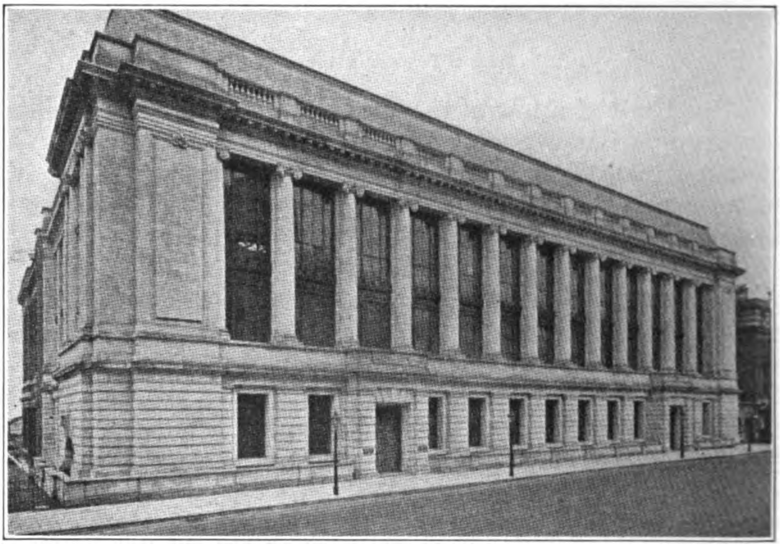
May I tell of a few of the things which I saw, as an illustration of what we desire to bring about? There is no difficulty in finding things to tell. The danger is that my enthusiasm will cause me to tell so much that I shall go beyond the limits of your endurance.

I recall my first visit to the Deutsches Museum in Munich. I had paid my respects to Dr. von Miller, the creator and life of that great institution. He had asked if he might give me a very cursory view of the collections before he turned me over to a young man. So we went first to the section on Physics. After going through the Court of Honor, where honor is paid to the immortals of German science, and through two rooms devoted to time keepers, clocks, watches, and sundials, we entered into Physics. Among the earliest things which we saw was a device to prove the relatively slight friction of a ball-bearing in comparison with a sliding bearing. That was easy. One twist of two wrists and the thing was done. But then the real question, *why is* rolling friction less than sliding friction? Can this be answered experimentally? I think it can be, and in an interesting manner.

Then there was a rotating table, on ball bearings, on which a man could stand within a rather closely fitting iron-pipe railing. Taking into his hands a special gyroscope set into brisk rotation, the man on the table underwent many twists and turnings when he tried to turn the gyroscope one way or another. He was led directly into some sort of an appreciation of the behavior of the gyroscopic compass and of the mono-rail car, and at the same time was immensely entertained!

We might well incorporate in the museum a section for the special benefit of college professors and ministers, on the subject of "perpetual motion." It would be a real contribution to human welfare to show the physical principles which demonstrate that perpetual motion is not a possibility—to attempt an experimental answer to the questions, "Why?" and "Why not?" I mention these two classes of good

FIG. 7.



Science Museum—London

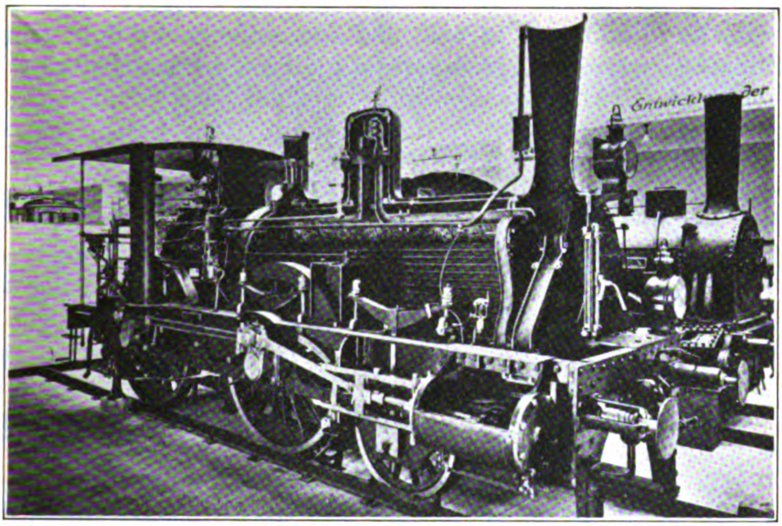
citizens because of the fact that every fake in physical science of the character of perpetual motion has victimized some of these distinguished persons.

We should want to be able to answer, or, much better, to enable a visitor to answer for himself, the question, "How can an aëroplane, which weighs tons, rise into the air in spite of the pull of gravity?" We can show this experimentally and strikingly in a very simple way, and we can show what are the things which determine whether or not an aëroplane will be able to leave the ground. All of this can be shown by simple experiments so that he who runs, or walks by, may understand.

We are all familiar with the steam locomotive but do we

really understand why it is able to pull a train of fifty loaded freight cars behind it? Is it enough to say that it is done by the expansive power of steam? We should propose to show by model engines cut away, so that all of the essential parts are visible, how the expansive power of a gas can possibly be made to do such a tremendous amount of work at such a great rate.

FIG. 8.



Sectioned Locomotive.

The radio telephone, marvelous as it is, has become one of the commonplaces of our lives. We take it as a matter of course. Veritable children can operate it, can repair it when it gets out of order, can talk of 'ticklers' and 'regeneration' and 'static,' quantities which ten years ago were hardly dreamed of. Yet, how much of *real* understanding is involved in such things? Very little, I fear. Would it not be an interesting and profitable thing to have shown by simple experiments the fundamentals underlying radio? I think it can be done and, also, that we can show, step by step, so that all normal men can understand, the development which has led from the crude apparatus of a few years ago to the exquisite scientific instrument which the radio is today. We

shall certainly make a valiant effort to make it all clear, and, in the process, to explain the working of that household marvel, the common telephone.

A question of domestic importance concerns our ability to match colors by artificial light. Can we do so successfully? Why, or, why not? I saw a beautiful attempt to make comprehensible the answers to these questions, at the Deutsches Museum. A pheasant, gorgeously feathered, rivalling the peacock in his coloring, was so placed that he could be illuminated at will, and successively, by light from different sources and of differing qualities. First, light from an ordinary carbon wick incandescent lamp was turned on the bird. He shone only fairly brightly; then light from a tungsten lamp was applied; the bird appeared brighter and more colored; then light from a so-called "day-light" lamp: the pheasant possessed all the beauty, apparently, which he showed in sunlight. Lastly, the light from a source of ultra-violet light was used—and the bird which had seemed so highly colored in reds and yellows, appeared as black as a black derby hat. The dependence of the apparent color upon the nature of the illuminant used, was clear beyond question.

What causes near-sightedness and what causes far-sightedness? How can these defects be remedied by glasses? How are such glasses ground? We shall try to show you.

The illustrations which I have taken have been from the realm of physics. Let us turn to Chemistry.

What is the difference between alchemy and chemistry? What is organic chemistry? And what is inorganic chemistry? How do they enter into our daily affairs?

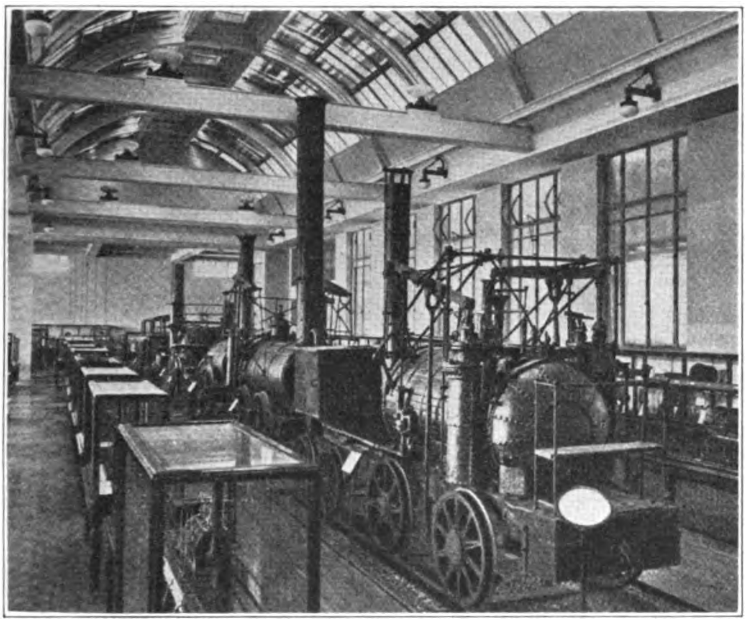
In one of the foreign museums there is the famous 'coal tar tree.' Starting with a lump of coal, the production of more than two thousand compounds is delineated, by a striking wall chart, in which is shown the exact 'descent' of each substance.

I think it would be an interesting thing to have a 'wood pulp tree.' Starting with the limb of a tree, such a "tree" would show the many things which are made from wood pulp —paper for our newspaper, cellulose, artificial silk for fabrication into silk stockings to be worn on limbs not at all wooden, and the many other materials derived directly from wood.

Take the glass industry. What is flint glass? Lead glass? Crown glass? How was glass originally made? How is it made today? What makes plate-glass? What is the U-viol glass?

We shall try to answer all of these, and other, questions by means of models of glass factories, by charts, by samples. We shall if possible, have a skilled glass-blower working at certain announced times, making apparatus which can later be used in

FIG. 9.



Original Locomotives.

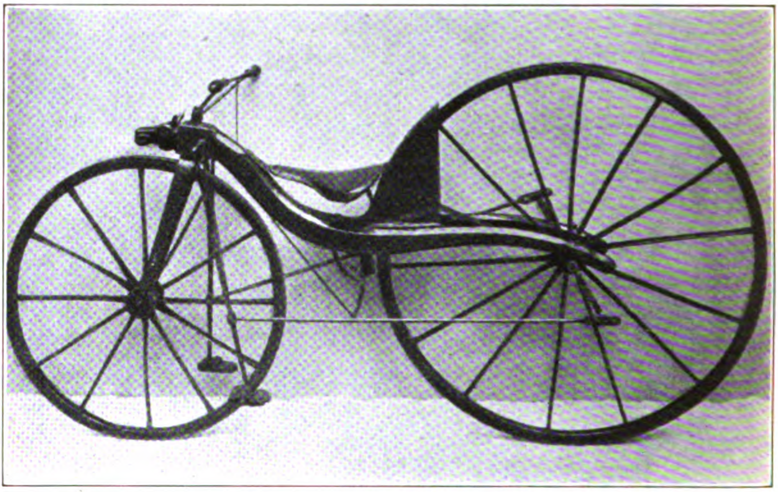
research. Few things prove more interesting to watch than the art of a skilled glass-blower. Perhaps we shall enable some young boys to find that they are meant by nature to be glass-blowers? Who can tell?

Philadelphia was the center of the chemical industries a century ago and has remained so to this day in certain lines of production. Models of factories or furnaces or plants, made to scale, will show how sulphuric acid or zinc oxide or lead storage batteries or any one of many other substances are

made commercially. And every effort and every suitable device will be used to make readily understandable all the scientific principles applied in these processes.

Consider engineering and industry. Pennsylvania and New Jersey are the birthplace of American railroads, and Philadelphia has been for decades the place of production of thousands of locomotives which have traversed all the "rails" of the world. This city has been the starting point for

FIG. 10.



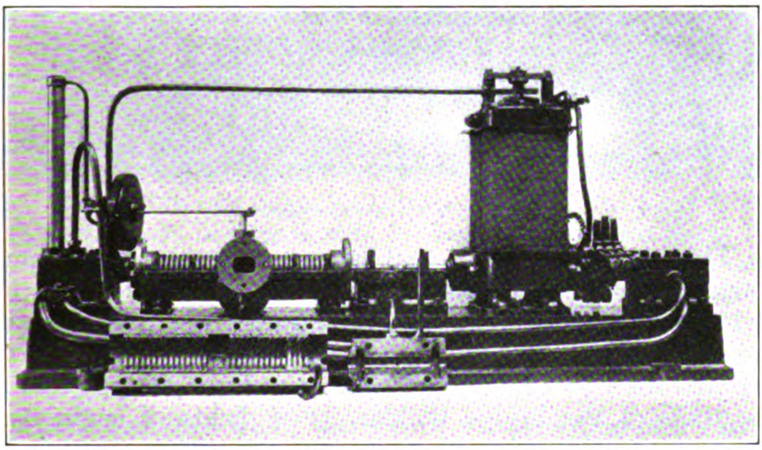
Bone-Racker Bicycle.

countless trolley cars which have extended urban and interurban transportation over the whole of this country. And hundreds of ships for commerce, for pleasure, for peace, for war, which have riven the waters of the "Seven Seas" and of all other seas, made their initial plunge into salt water from the banks of the Delaware.

These facts, coupled with the historical incident that one of the founders of The Franklin Institute was the first president of Pennsylvania Railroad, make it most appropriate that we should devote full attention to the history of transportation and to the portrayal of the expansions of science which have made modern transportation a possibility.

We shall portray the changing methods of travel from riding on the horse's back to the unforgettable voyage of the "Lone Eagle" in the *Spirit of St. Louis*, from the arduous journeys of the American Indian in his birch-bark or his "dug-out" to the luxurious and safe crossings of the *Leviathan*, from the miseries of the "bone-racker" bicycle to the comfort of the Lincoln car. And our constant purpose must be to show the logical evolution which has led from one vehicle to the next, from one method of transport to the next, and the

FIG. 11.



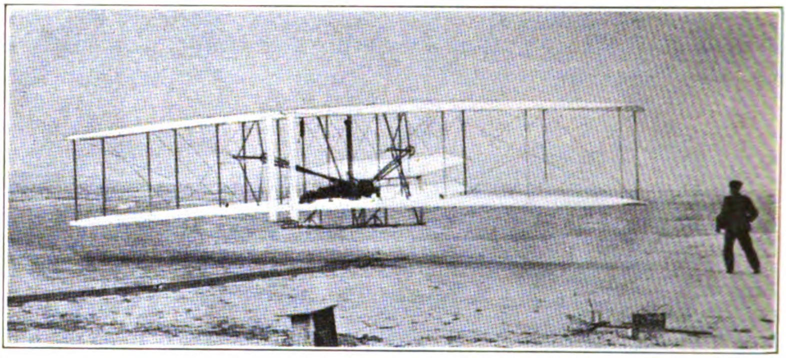
Early Steam Turbine.

fundamental discoveries which find their applications in the useful service of man. The exhibit devoted to transportation is one of the largest and most interesting in every museum because, probably, improved transportation has always been the goal which men constantly seek, and because of the fundamental importance of the subject.

So we shall try to make as plain as sunlight the action of steam engines, steam turbines, windmills, water-wheels, gas-engines, Diesel engines, electric motors, tidal motors and all other prime movers which do the work of man. We must show the development of the latest railroad flyer from the "*Rocket*" of Stephenson, the evolution of the *Aquitania* from

the "*Claremont*" of Fulton, the direct descent of Byrd's North Pole aëroplane from the Kitty Hawk machine of Wilbur and Orville Wright. In every step, the scientific "why" must be pointed out and made understandable.

FIG. 12.



Original Wright Aeroplane.

The growth of bridge-building must be pictured, from a single tree thrown down across a brook to the beautiful Delaware River bridge. The accessories which have made the latter bridge and its like possible must be shown: power dredges, diving bells, caissons, piling and pile drivers, and all the tools of the bridge builder. Few fields of engineering show so many inspiring examples of the conquest of nature by man's courage and intellect as the science of bridge-building. Every great new bridge has brought some new feature into the work, some improvement of former methods, some method of adopting ancient knowledge, or of applying modern information, to novel and trying problems.

Consider some of the problems which even the most ignorant of us must realize have to be solved when a tunnel is run under a great river, as the Pennsylvania Railroad tunnel under the Hudson River.

How is the hole through the earth and the rock and the mud made? How can men be enabled to work scores, and even hundreds, of feet below the surface of the water? What are the tools which make such things possible? How do such tools work? What are the advantages and the disadvantages

of electric tools in comparison with steam, or pneumatic, or mechanical tools? After the tunnel boring is made, how is the tunnel tube put into place? How is it fixed? How is it supported? What effect upon the railroad tunnel has the passage up the Hudson of a huge ocean liner? How many different ways might the tunnel work be done?

You can see readily enough what kind of problems might arise, what varied questions may demand answers. And I think you will realize what an interesting exhibit ought to be possible. Such an exhibit must give the answers required by means of physical experiments, if that be possible.

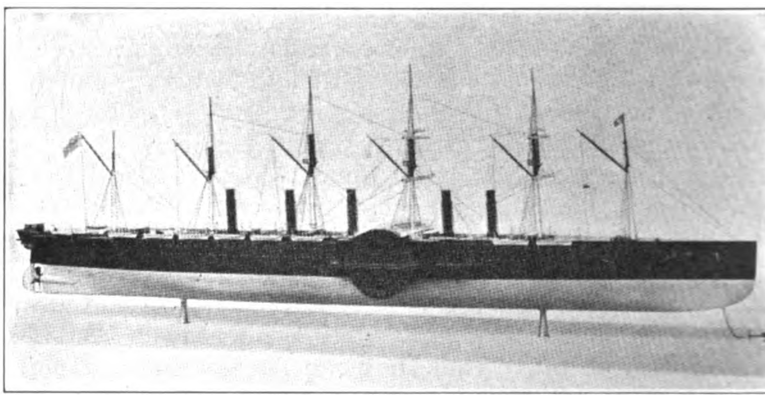
Of course one of the world's great engineering accomplishments is the Panama Canal. Problems which seemed insoluble were met and solved, new methods were planned, new tools were made and successfully used. Engineering feats on an unprecedented scale seem almost commonplaces in the Canal Zone! Locks large enough to pass a battleship, or an ocean liner, from one canal level to a different one, have been built and are in use, problems in drainage, in sanitation, in construction have been ingeniously solved. Can the solutions of these problems be portrayed experimentally? We shall certainly try to prove that they can be—for the instruction and training of all who are interested.

Probably no more generally attractive exhibit can be prepared than that which deals with the evolution of modern boats from the savage's dug-out, "ein-baum," as the Germans call it, through the craft driven by man-power or by winds and sails, down to the giant liners of today, or the Flettner motor ship. Some of the collections of ship models, especially that at Munich or in the Science Museum in London, are extremely interesting and attract great attention at all times. Such displays are especially impressive when, as in the Science Museum, models are constructed to the same scale and so show the growth and development from ship to ship. Four such models of Cunard ships, four boats which were the pride of the line when they were launched, show most strikingly the increases of size and of comfort of the ships of that great transportation company during the last thirty or forty years.

Such collections should not be merely attractive to the eye. They should always be regarded as teaching some application

of science to the uses of mankind. Such models can be used to illustrate the dependence of the sea-worthiness of a boat upon the shape of the hull, the distribution of the equipment, and the stowing of the cargo. Such models can be made to show what is meant by "Stream-line form" of the hull, and perhaps also, the dependence of the speed on such form, with unchanging power. One can readily demonstrate, experimentally, the behavior of the Flettner motor ship and can

FIG. 13.



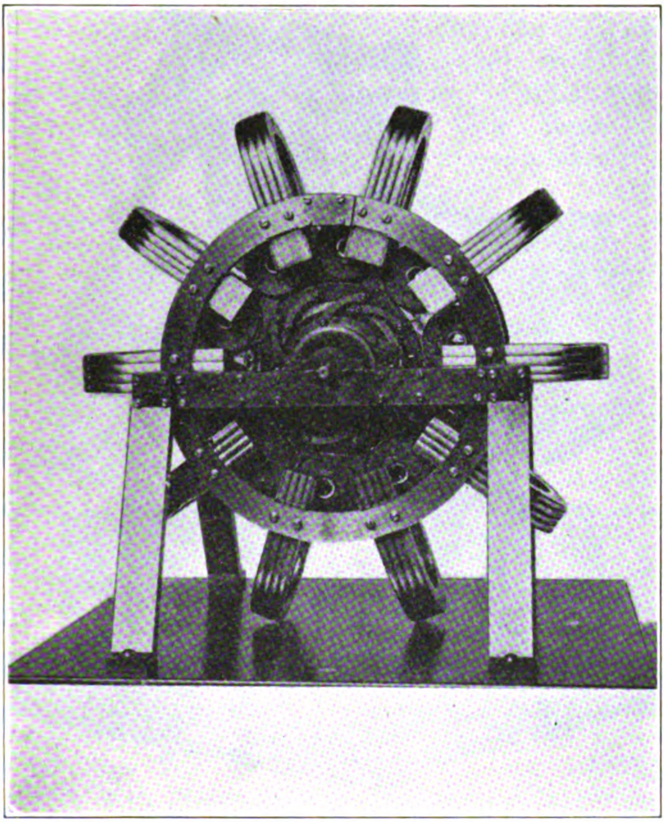
The Great Eastern.

"explain" its working. And one can show by very simple experimentation that the physical principle, or law, underlying the motion of the Flettner craft explains also various apparently unrelated actions, such as the curving of the pitched baseball, the production of the sensation of fullness of the ears when a rapidly running train goes through a closely fitting tunnel, or the behavior of the ball in "the ball and jet." Surely here is a chance to show the unification of science!

I recall a portion of the exhibit concerning boats of the Deutsches Museum of Munich in which the cabins, first or second or third class, and the corresponding dining saloons, are shown in their exact proportions. The engine rooms, erected to scale, with engines running, and the ships-bridge, displaying the signalling apparatus and the navigation instruments, are to be visited and inspected. Then, the onlooker is led to the promenade deck, where steamer-chair, steamer rugs

and the appliances for the comfort of the passengers are shown. There, beyond the rail, is shown a painted ocean! The illusion is so complete that the spectators receive a vivid impression of reality. The person who has never been near

FIG. 14.



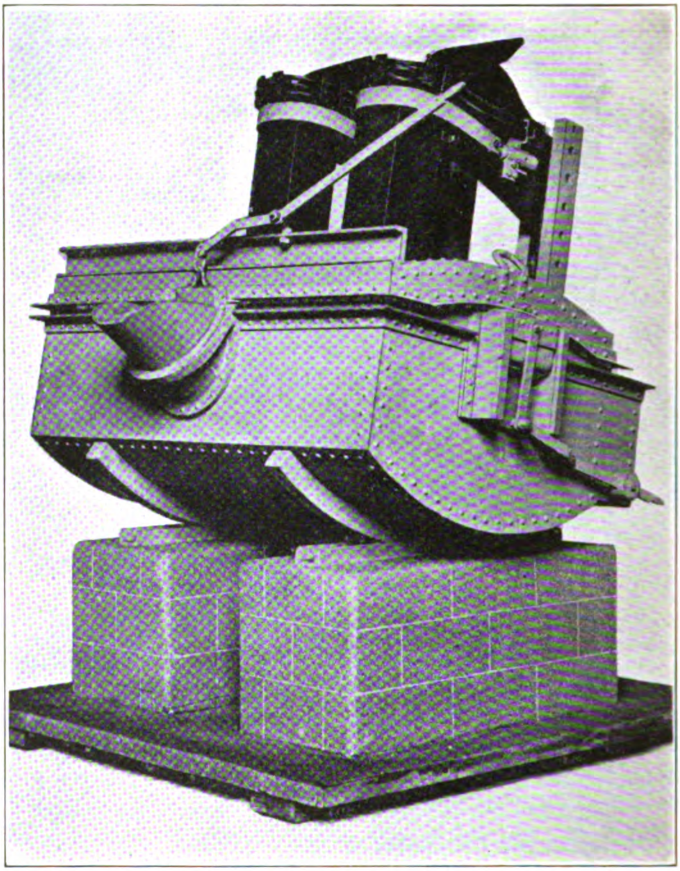
Early Dynamo.

the ocean may obtain a reasonable understanding of the atmosphere of a trans-oceanic steamer.

A necessary adjunct of ocean shipping, required that ships may be kept in good condition or repaired when damaged, is the dry dock, whether a fixed or floating dock. Working models of both types should be shown so that the veriest land-

lubber cannot fail to understand this great nautical tool and the ingenious applications of science which are made in the dry-dock structure and working.

FIG. 15.



Electric Arc Furnace.

In this era, when we talk, or think, of engineering and its practices, we come, sooner or later, to constructions and operations of electrical engineering. We are soon confronted by the marvels effected by the electrical men, hundreds of them, in lighting, in communication, in transmission of

power, in transportation, in construction of stupendous machines, in the erection of beautiful and powerful hydroelectric power-plants. In no field have more ingenuity and more exact knowledge been utilized than here. And in no community has greater progress been made, or more success been attained, in the application of electrical power to the home, to the factory, to daily life, than here in Philadelphia. The great power plants of the Philadelphia Electric Company and the magnificent Conowingo power plant on the Susquehanna River show the highest efficiencies yet attained by man in the generation of electric currents by either steam or water power. They are, as yet, the last word in electrical planning and construction. They are due in large part to the engineering knowledge, the administrative ability and the indomitable will of the late honored president of The Franklin Institute, Dr. W. C. L. Eglin, Chief Engineer of the Philadelphia Electric Company. We should be remiss if we did not show, as a special feature of our electrical exhibit, working models of some of these great engineering structures which have given to Philadelphia a position of fine leadership. We shall strive earnestly not to be remiss in this respect.

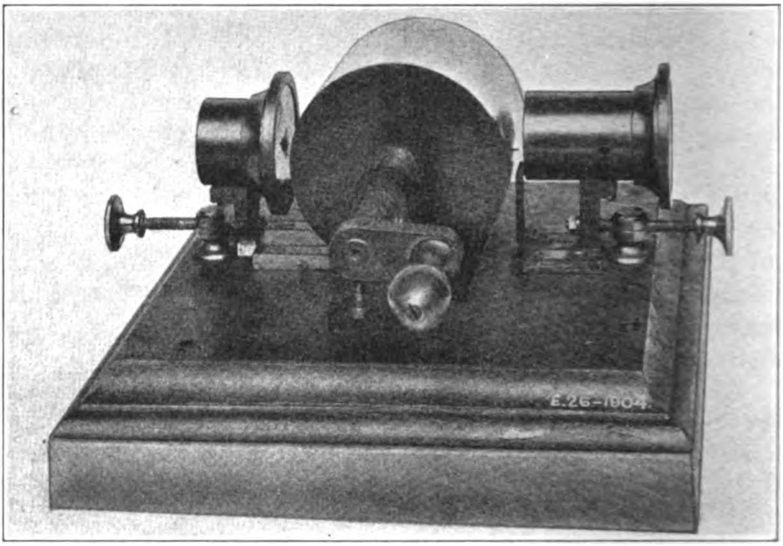
A portion of our agreement with the Benjamin Franklin Memorial, Inc., calls for the establishment and maintenance of an exhibit of the graphic arts as they were at the time of Franklin's activity as a printer. We should expect to display much more, for we should want to show many things which Franklin had not even dreamed of. We shall want to show printing as it was done in Franklin's shop and as it is done today in great modern plants. We shall portray the processes of engraving as practiced then, and as they are utilized today, and also how they are facilitated by the application of electrolysis and photography. We shall demonstrate the making of paper, whether rag or wood-pulp, and bookbinding, the development of printing and typesetting machines and the several auxiliaries of the present printer's art.

One of our ambitions is to show photography in such a way that a "tyro" can have some informed appreciation of it, as well as learn the actual manipulations involved. It will perhaps be possible to set forth the growth of modern photographing from the labors of Daguerre to those of Eastman, on

through the moving picture, through color photography to the color-movie. The preparation of such an exhibit offers an intriguing problem.

The analysis, recording and reproduction of speech offer another enticing region for experimental demonstration. It should, I think, be readily possible to start with the manometric flame, show the varying quality of the sounds produced

FIG. 16.



Original Edison Phonograph.

with changes of shape of the sound waves; then, to show the recording of such waves by the crude original apparatus of Edison and by the methods of Berliner and others, as well as to make clear the ways which have been, or are now, practiced in reproducing such sounds. It should not then be over difficult to demonstrate the production of synchronism between light and sound, say by the method of Bristol, and thus to make clear the evolution of the successful talking motion picture.

In an effort to make wholly clear to you what are to be the purpose and nature of the much discussed museum, many illustrations have been taken from various fields of physical

science. Even though a considerable number have been described, they represent only "samples" of the almost countless examples of the applications of science to man's use

FIG. 17.

Iron Workers Shop.

and welfare which might have been chosen and which will be found displayed in the completed museum. We might have chosen many more illustrations, from engineering, from mining, from geology, from manufacturing, from domestic

affairs, from city life, from the farm, from our work, from our play. Perhaps what have been chosen will suffice.

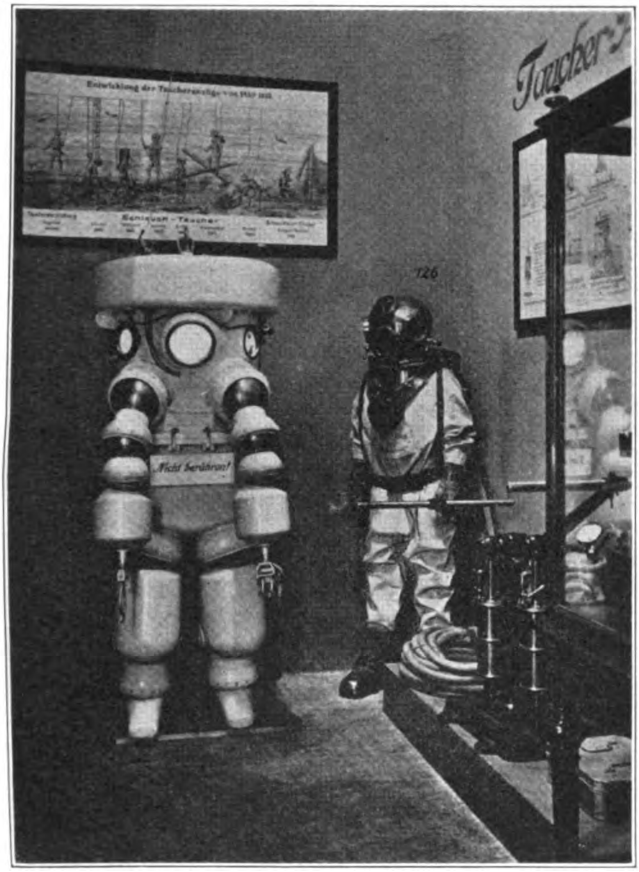
We hope earnestly that the examples cited will show two things: how excitingly interesting such a museum as has been planned can be, and that it should be a place where many a young person may be aided, through increased knowledge, to learn of his own abilities and tastes and, therefore, to make a wiser choice of his life's work. That the first of these results may be confidently hoped for is indicated by the effects of the great European scientific museums upon the visitors to them. It is the common thing to hear of the traveler who goes to Munich to see all the beauties of that city and goes first to the Deutsches Museum—"to get through with that"—and who then goes again and again and again, to the complete neglect of all other museums and collections. One of the three or four leading physicists of the United States said, when asked if he had gone to the Deutsches Museum and if he had enjoyed it: "I spent three full days there, and wish that I might have had three full weeks." One of the great industrialists of this country volunteered the statement, "I never go to London without making at least one visit to the Science Museum in South Kensington." We mean to give to Philadelphia an equivalent institution.

If the museum performs the second service which is expected of it and aids young people to make wise choices of vocation, then it will indeed be a worthy and living memorial to Benjamin Franklin. You will recall Franklin's expression of approval of his father's action in taking him to visit various industrial plants in the hope that he would be thereby aided in choosing his line of future activity. No one could value more highly than Franklin would have done an institution which would have as an important by-product of its activities, helpfulness to young people in the choice of their occupations for life.

One thing the museum will accomplish, whatever else it may, or may not, bring about. It will give to the young people of school age a realization of the vitality and importance of scientific knowledge. It will show convincingly how valuably science may be applied for man's advantage. It cannot fail to inculcate, by analogy, a belief in the value of

all knowledge. The museum will be a vital adjunct to the educational facilities of the city.

FIG. 18.



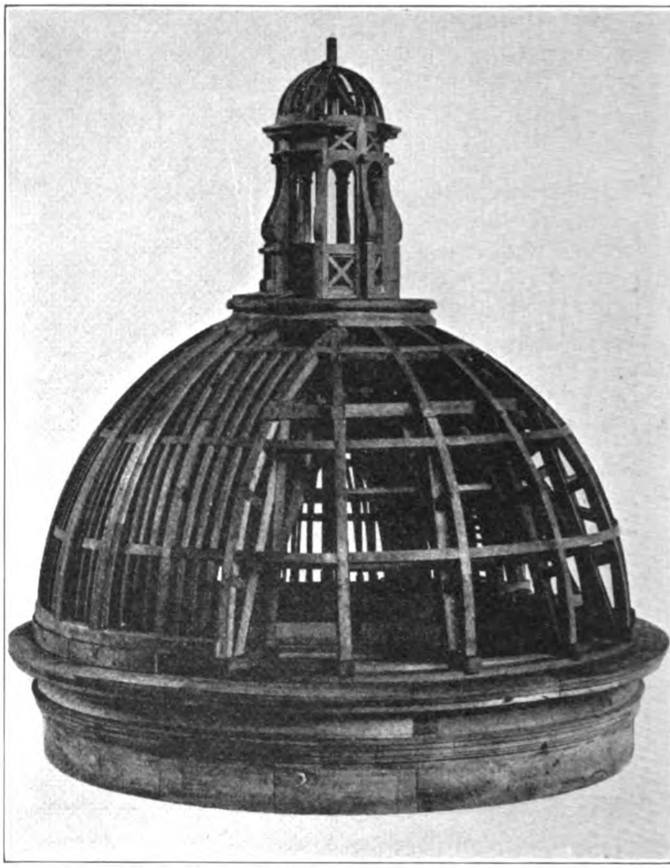
Deep Sea Diver.

I have refrained deliberately from mentioning, up to this time, one field of scientific thought in which this new institution can contribute in a striking way to the enjoyment and enlightenment of the people—the science of astronomy.

Our earliest progenitors lived under the stars, and could not avoid thought, even wonderment, about them and their

mystery. The literature of the ancients of every nation abounds in reference to the heavenly bodies. The very names of the constellations show the imagination which was applied in their thoughts about the stars. Under modern

FIG. 19.



Framing of Cathedral Dome.

conditions of living, especially in the great centers of population like Philadelphia, a knowledge of the stars—often even a view of them—is obtained only with difficulty. So it is but natural that the old intimate acquaintance with the stars should have become very rare. We doubtless know tre-

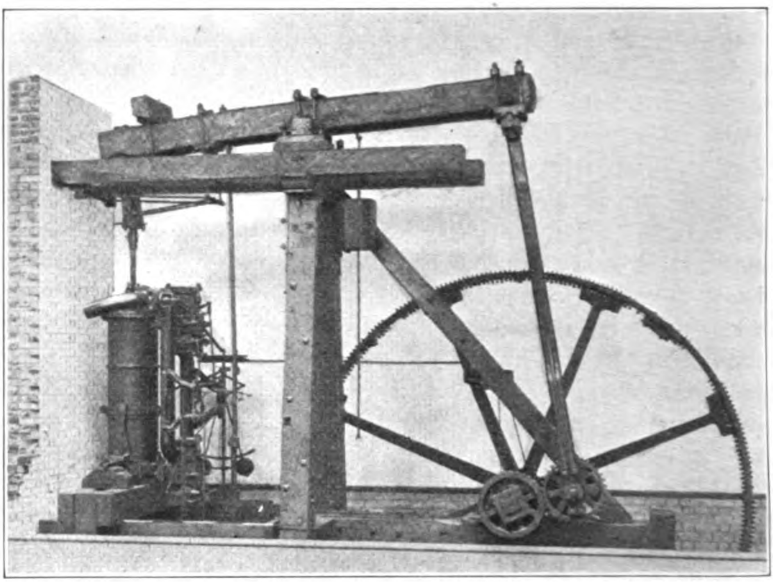
mendously more of the science of the stars. I doubt if we know them so well as one of the wonders of the universe as our fathers did.

We wish greatly to be able to show in the museum a great planetarium which portrays the heavens so beautifully and in such glory that one gets a splendid conception of them. This great scientific instrument projects upon the inner surface of a hemispherical dome thousands of lights which represent accurately and in approximate magnitude the fixed stars as we behold them on a clear night. Other, and special, lights portray the Sun and its planets, the Earth and its satellite, Venus, Mercury, Mars, Jupiter and its moons, Saturn with its rings, in proper relative magnitude and position and, by their motions, the motions of these planets in their proper periods and orbits. The motions of a year can be shown in four minutes or sixty seconds or seven seconds. One can see clearly the elliptical form of the orbits, without waiting years, or centuries, to do so. One readily realizes the effect of the inclination of the plane of the ecliptic in producing the earth's seasons. One sees why the present 'pole-star' has not always been our 'pole star' and one can see what star will be our 'pole-star' thousands of years hence. By easy and suitable regulation, the audience can be shown the heavens as they appear to an Eskimo, or as they might have appeared to Captain Scott at the South Pole, or as they will appear to Commander Byrd when he reaches that remote axis, assuming that he will have clear nights. By other adjustments, the sky can be depicted as it appeared to Abraham thousands of years ago, "as he tended his flocks by night," or as it will appear to the "Last American" thousands of years hence. The great beauties of the skies are brought out with such force and effectiveness that the onlooker exclaims with the Psalmist, "The heavens declare the glory of God and the firmament showeth His handiwork." At least, that was the effect upon the writer when he saw this great product of man's intellect during this past summer.

In addition to the planetarium, we shall have telescopes, both reflecting and refracting, for direct visual observations of the heavens, and enough of other types of apparatus to give some insight into the wonders and the successes of modern

astronomy. We are promised copies of the finest photographs ever taken of many spiral nebulæ, eclipses, comets and other astronomical objects and phenomena. We shall surely have an astronomical exhibit which will be worthy of this home of Rittenhouse, if we have a museum at all!

FIG. 20.



Ancient Steam Engine.

I have tried to give you some insight into the vision we have had of a great new home of science and scientific wonders, built and maintained for the benefit and enjoyment of Philadelphia and its visitors. We hope it will gain your approval and support. We shall earnestly strive to make it a place of profit and pleasure for you and your children and your children's children for uncounted generations.

THE POSSIBILITY OF DETECTING INDIVIDUAL COSMIC RAYS.

BY

W. F. G. SWANN, D.Sc.

Director, Bartol Research Foundation of The Franklin Institute.

THE purpose of the present paper is to show that, in view of the enormous energy available for ionization in a single cosmic ray, and of the relatively small number of ions produced per second by the rays in a vessel of moderate size, the ionization produced should occur in spurts which may be observable under suitable conditions.

According to Millikan and Cameron, the rays observed near the earth's surface have an absorption coefficient of about 0.1 per meter of water, and produce about 1.4 ions per c.c. per second in air at atmospheric pressure.[1]

Using Dirac's formula,[2] the value of $h\nu$, the cosmic ray energy, corresponding to $\mu = 0.1$ per meter of water is

[1] In Millikan's and Cameron's paper, *Nature*, Supplement, Jan. 27, 1928, the authors quote the present writer as having obtained the value 0.75 ions per c.c. at the summit of Pike's Peak. It must be remarked that the latter quantity is the increase per atmosphere in the ionization per c.c. at the part of the ionization-pressure curve where the slope is least. This quantity has no very simple relation to the ionization per c.c. at atmospheric pressure. It should be less than the latter quantity. In discussing the relation between pressure and ionization, the writer demonstrated the following theorem in the Bulletin of the National Research Council, No. 17, pp. 54–77, 1922. The increase in ionization per atmosphere increase in pressure in a vessel is greater than the portion of the ionization due to primary and secondary action arising *in the gas within the vessel* at one atmosphere. (Footnote to above: It would not be quite safe to extend this argument to imply that the ionization here referred to was necessarily greater than the true natural ionization in the open air, since a portion of the ionization in a volume of the external air occupying the space of the vessel would result from secondary radiations originating outside of that volume.)

The words italicized in the above, and the footnote are very important since, in the case of long range secondary radiation, a considerable portion, and probably the main portion of the ionization comes from secondary radiation originating outside the vessel, or in the walls of the vessel.

[2] Dirac, *Proc. Roy. Soc.*, A 111, 423, 1926.

13×10^{-5} ergs per cosmic ray. If all of this energy is available for ionization, the number of ions producible by a cosmic ray by direct and secondary actions should be $h\nu/Ue$, where U is the ionization potential. Taking U as corresponding to 15 volts for nitrogen, we find

$$\text{Number of ions per cosmic ray} = \frac{h\nu}{Ue} = 0.54 \times 10^7.$$

If the average rate of production of ions by cosmic rays is N ions per c.c. per second at atmospheric pressure, the average number of primary cosmic rays absorbed per second in a volume W is n, where

$$n = \frac{NUeW}{h\nu} \tag{1}$$

Of course, all of the ions resulting from the absorption of a primary quantum in a volume W do not make their appearance in that volume. Many of them are produced by secondary radiations which go outside of the volume. Again, secondary radiation originating from the absorption of quanta outside of the volume enter it and produce ions there. The rate of production of ions in a volume is, however, equal in air to $h\nu/Ue$ times the average number of primary quanta absorbed in the volume per second.

If the ions produced by the direct and indirect results of the absorption of a primary quantum were all produced in the immediate vicinity of the point of absorption of the quantum, we should obtain in our volume W, n spurts of ions per second. As a matter of fact, we should under these conditions obtain 0.54×10^7 ions at each spurt; and, as may be seen by inserting $N = 1.4$ in (1) we should obtain only $1.4\ W/0.54 \times 10^{-7} = 2.6 \times 10^{-7}\ W$ spurts per second.[3] In other words, in a volume of 1 liter, there would be an interval of 4,000 seconds

[3] Incidentally, this conclusion has an interesting bearing upon experiments designed to test whether radioactivity may be caused by disintegration of the radioactive atoms by cosmic rays. Thus, in a test made with, let us say, 10^{-11} grams of polonium, which would give a saturation of about 0.3 e.s.u., we should have to wait about 10^{15} seconds, or about twenty million years between two successive occasions on which a cosmic ray became absorbed in our radioactive specimen.

between each spurt. In practise, the conditions are otherwise. The ions are produced for the most part by secondary radiation which operate far from the place of absorption of the original quantum.

We shall first consider an ideal problem which probably does not represent the facts in their details, but which will nevertheless illustrate the general principles which enter into a consideration of the problem. We shall suppose that the secondary radiation resulting from the absorption of a primary quantum may be regarded as producing ionization (in ions per c.c.) which falls off according to the symmetrical exponential law,

$$I = \frac{I_0 e^{-\alpha r}}{4\pi r^2},$$

where r is the distance from the point of absorption of the original quantum. I_0 is determined by the condition

$$\frac{h\nu}{Ue} = I_0 \int_0^\infty \frac{4\pi r^2 e^{-\alpha r}}{4\pi r^2} dr = \frac{I_0}{\alpha}.$$

Hence

$$I = \frac{h\nu\alpha}{Ue}\frac{e^{-\alpha r}}{4\pi r^2}.$$

Let us now consider the ionization produced in a spherical vessel of radius a, Fig. 1, as a result of the secondary radiations originating from the absorption of a primary cosmic ray at a point P at a distance b from the center of the sphere. The part of this ionization per c.c. at the piont A is

$$\frac{h\nu\alpha}{4\pi Ue}\frac{1}{k^2 + b^2 - 2bk\cos\theta}e^{-\alpha l}, \tag{2}$$

where $AO = k$, and $AP = \sqrt{k^2 + b^2 - 2bk\cos\theta} = l.$

The number of ions produced in the element of volume $k^2 \sin\theta\, dk d\theta d\varphi$ is

$$\frac{h\nu\alpha}{4\pi Ue}\frac{k^2 \sin\theta dk d\theta d\varphi}{k^2 + b^2 - 2bk\cos\theta}e^{-\alpha l}. \tag{3}$$

Hence, since the exponential factor is less than unity, we have for the total ionization ΔN within the vessel

$$\Delta N < \frac{h\nu\alpha}{4\pi Ue}\int_0^a k^2dk\int_0^{\pi}\frac{\sin\theta d\theta}{k^2+b^2-2bk\cos\theta}\int_0^{2\pi}d\varphi, \quad (4)$$

$$\Delta N < \frac{h\nu\alpha}{2Ueb}\int_0^a k\log\frac{b+k}{b-k}dk,$$

$$\Delta N < \frac{h\nu\alpha}{2Ueb}\left[ba - \frac{b^2-a^2}{2}\log\frac{b+a}{b-a}\right].$$

$$\Delta N < \frac{h\nu\alpha a}{2Ue}\left[1 - \frac{(b-a)(b+a)}{2ba}\log\frac{b+a}{b-a}\right]. \quad (5)$$

For the case where P lies outside, or at any rate, not inside, the vessel ΔN has its largest value for $b - a = 0$, and for this case

$$\Delta N < \frac{h\nu\alpha a}{2Ue}.$$

If we should fill the vessel to p atmospheres pressure, and if we should assume the ionization proportional to the pressure, we should have [4]

$$\Delta N < \frac{h\nu\alpha p a}{2Ue}.$$

Cosmic rays absorbed at points P within the radius a, give, in the whole volume, an ionization greater than that resulting from those absorbed on the boundary of the volume, as may be seen from (5). It must be admitted, however, that this conclusion would be modified in practice by the fact that the secondary ionization would not spread out uniformly in all directions.

Let us suppose that 10^5 ions is the least number which can be detected, since the collection of this number would result in a deflection of 2.5 mm. in an electrometer sensitive to 3,000 divisions per volt, with a capacity equal to 20. Then for *every* cosmic ray absorbed within the vessel to give rise to a measurable effect we must have

$$a > \frac{10^5 \times 2Ue}{\alpha p h\nu}.$$

[4] There is some doubt as to whether ΔN would be proportional to the pressure up to 100 atmospheres, and if it varied less than according to the law of proportionality, n would be reduced on this account also.

Putting $h\nu/Ue = 0.54 \times 10^7$ as already found, putting $\alpha = 4 \times 10^{-5}$ which is about the same as the absorption coefficient of the γ rays from radium C, and putting $p = 100$ atmospheres, we find

$$a > 10 \text{ cms.}$$

With any such radius as this, the exponential factor $e^{-\alpha l}$ in (2) is quite negligible. For, with the above value of α multiplied by 100 to take account of the pressure, αl would only amount to 4×10^{-2}. Thus, in view of this circumstance, our signs $<$ and $>$ might have been written $\leq$ and $\geq$ respectively, all the way through, and our final conclusion is that to obtain a spurt of 10^5 ions as the ultimate result of the absorption of a primary quantum at the surface of the sphere, we must have

$$a \geq 10 \text{ cms.}$$

The number of primary cosmic rays effective per second in giving measurable spurts of ions are consequently those absorbed per second within the volume $\frac{4}{3}\pi a^3$. From (1), this number is $\frac{4}{3}\pi a^3(NUe/h\nu)p$, where the factor p has been introduced to account for the enhanced absorption of cosmic rays as a result of the pressure. To obtain 10 spurts per second, we must have $a = 45$, which would be impracticable at 100 atmospheres. To obtain 1 spurt per second from cosmic rays absorbed within the vessel we must have a about 21 cms., and to obtain .1 spurt in 10 seconds, we must have a about 9.7 cms., which is within the range of practicability.

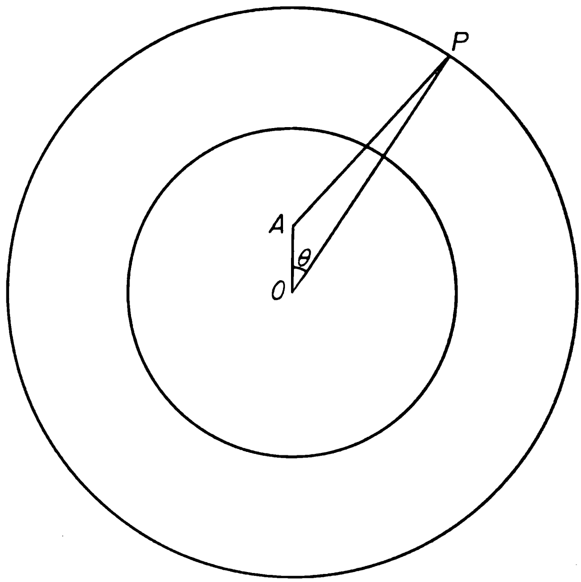
A METHOD OF INCREASING THE POTENTIALITIES OF THE EXPERIMENT.

The element which acts unfavorably to the purpose of the experiment is that concerned with the fact that the number of primary cosmic rays absorbed per unit of volume is so small that it is very rarely that a cosmic ray is absorbed so near to the vessel as to cause by its secondary radiations a large ionization therein. We may improve matters in this respect by surrounding the vessel with a highly absorbing material such as lead.

Thus, using Fig. 1 in an altered sense, and with the ionization chamber surrounded by lead, suppose we consider a

sphere of radius a surrounded by a lead shell whose outer radius is R. We shall neglect the variation of the intensity of the primary cosmic rays throughout the region of this shell. Of the cosmic rays generated in the shell, those produced on its

FIG. 1.



exterior will be the least efficient in giving rise by secondary radiations to ionization in the ionization chamber. According to (2) modified to fit the present case, the ionization per c.c. at a point A in the vessel resulting from a primary cosmic ray absorbed at a point P is

$$\frac{h\nu\alpha}{4\pi Ue}\,\frac{e^{(-\alpha r_1+\alpha_2 r_2)}}{R^2+k^2-2Rk\cos\theta}$$

where r_1 refers to the part of AP which is in the air and α_2 and r_2 to the part in the lead. If then, the exponential were negligible, we should have for the above

$$\frac{h\nu\alpha}{4\pi Ue(R^2+k^2-2Rk\cos\theta}.$$

Again, proceeding as before, we find for the total number of ions produced in the vessel as a result of the absorption of the primary quantum at P,

$$\Delta N = \frac{h\nu\alpha a}{2Ue}\left[1 - \frac{(R - a)(R + a)}{2aR}\log\frac{R + a}{R - a}\right].$$

For a given value of a this, of course, has its greatest value when $R = a$. For this case, however, the number of cosmic rays caught by the shell would be just equal to that already calculated for this case. If we make $R - a = 2$ cms., and $a = 15$ cms., the corresponding value of ΔN is $2.7 \times 10^7\alpha$. If we should raise the pressure in the vessel to 100 atmospheres and assume proportionality, the corresponding value of ΔN would be $2.7 \times 10^9\alpha$ and if $\alpha = 4 \times 10^{-5}$, the corresponding value of ΔN would be 1.0×10^5 and would be measurable. Moreover, the neglect of the exponential is roughly justified for the above conditions, as may readily be verified.

Now, however, we secure from the lead, an advantage in respect to the number n of cosmic rays which contribute per second measurable amounts of ionization ΔN corresponding to the above calculation. For the number we have, from (1), after taking account in addition to the cosmic rays caught in the ionization chamber,

$$n = \frac{4}{3}\pi(R^3 - a^3)\frac{NU_e}{h\nu}\frac{D_l}{D_a} + \frac{4}{3}\pi a^3\frac{NU_e}{h\nu}p,$$

when D_l/D_a is the ratio of the density of lead to that of air at atmospheric pressure, i.e., 0.9×10^4. Inserting $N = 1.4$, $h\nu/Ue = 0.54 \times 10^7$ as already used, and the above values of R and a, we obtain $n = 13$. Thus, with the above apparatus we should, on the basis of the above assumptions have obtained 13 spurts of ions per second, of amount greater than 10^5 ions. By choosing the volume of the lead one-tenth of the above, n would be reduced to 1.3 per second.

Of course, the assumption we have made cannot be expected to be correct in detail. In particular, the assumption of a symmetrically distributed secondary radiation dying off exponentially must be incorrect. Nevertheless, the foregoing calculations are sufficient to show the practicability of at-

tempting to detect effects due to the absorption of individual cosmic rays.

An experimental difficulty presents itself in respect to the time taken to clear out the ions in the case of a high pressure in the ionization chamber, for, in view of the relatively small mobility of the ions, a large electric field would be necessary to clear them out in such a time as to produce the phenomenon of a recognizable spurt.

Another type of assumption which probably departs from the facts in the opposite extreme to that already made, is to the effect that the secondary radiation may be considered as originating from the point of absorption of the primary ray, and then passing through space with little ionization except for a certain distance e_a (measured in air at atmosphere pressure) at the end of its path. Let us now suppose our ionization chamber of radius a surrounded by a shell of lead, as before. On working out the number of cosmic rays effective in producing spurts of ions, we obtain an expression of the same order of magnitude as in the last problem considered, except that a^3 is replaced by $a^2e_lD_l/D_a$, i.e., by a^2e_a where e_l is the range of the active part of the secondary ionization ray as measured in lead, If e_a is comparable with a, the value of n deduced is comparable with that already found.

It would, of course, be possible to develop the detailed story of the ionization of the secondary radiation by considering the successive transformations due to the Compton effect, but it seems hardly necessary to do this in order to illustrate the possibilities inherent in an experiment of the above kind.

THE TRANSMISSION OF SOUND THROUGH SEA WATER.

BY

LIEUTENANT (J.G.) JERRY H. SERVICE, E.E., Ph.D.

U. S. Coast and Geodetic Survey.

INTRODUCTION. WORK OF HECK AND SERVICE ON SPEED OF SOUND IN SEA WATER.

In 1924 Heck and Service published tables [1] giving the speed of sound in sea water at all depths, temperatures and salinities likely to be encountered in ocean waters. These tables were based upon the independent suggestion of Service in the fall of 1923 that if adequate elasticity and density data were available for sea water the speeds could best be obtained by computation by Newton's equation. Fortunately adequate elasticity data had been made available by the labors of V. W. Ekman [2] and excellent density data had been obtained by Martin Knudsen, Carl Forch, S. P. L. Sörensen and J. P. Jacobsen and published with due acknowledgements by Knudsen in several publications. V. Bjerknes and J. W. Sandström had published [3] tables, based upon the work of Ekman and of Knudsen and his collaboraters, giving the densities and specific volumes of sea water throughout the whole range of physical conditions, and with such small pressure intervals that the elasticities could be obtained by tabular differences. References to Knudsen's publications can be found in that of Bjerknes and Sandström.

At first sight it would seem to be much better to use Ekman's elasticity results directly, together with the density data published by Bjerknes and Sandström, in computing the speeds of sound. But Ekman stated that his elasticity data might be in error by as much as one per cent., which would mean that the speeds of sound computed by this much more laborious, although apparently more accurate, method might be in error by as much as 0.5 of one per cent. It was estimated that in speeds computed by the less laborious method of tabular differences from Bjerknes and Sandström's Tables, errors due to the method of computation would never exceed 0.5 of one per cent., and hence that speeds thus computed

would be of the same order of accuracy as if computed by the apparently more precise method.

Heck and Service used the isothermal elasticities of the water in computing their tables of speed, and included in a separate table corrections to these speeds to take care of the adiabatic conditions that might obtain during transmission; they expressed doubt at the time of publication (1924) as to whether these adiabatic corrections ought to be applied. The writer's experience with echo sounding and radio-acoustic position finding and his consideration of the matter since 1924 have convinced him fully that transmission takes place under adiabatic conditions.

The accuracy of the tables of Heck and Service, when the adiabatic corrections are applied, has been rather well confirmed by experiment and it is considered worth while to reproduce those tables in condensed, skeleton form in this publication. This has been done in Tables 1, 2 and 3, which indicate the manner of variation of the speed of sound in sea water with depth, temperature and salinity, respectively. The solid curves in Fig. 1 are plotted from the values of Heck and Service in Tables 1, 2 and 3. Attention is called to the following facts that are brought out by these tables and curves.

1. Speed increases with temperature approximately 0.2 of one per cent. per degree Centigrade.

2. Speed (at the given depth) increases quite regularly with depth, about 0.2 of one per cent. per 100 fathoms.

TABLE 1.

Variation of Speed of Sound in Sea Water with Depth.

Temperature, 0° C. Salinity, 35 parts per 1000. Depths are in fathoms; speeds, in meters per second.

Depth.	Speed Heck and Service.	Speed British Admiralty.
0	1450	1445
500	1464	1462
1100	1482	1482
1700	1504	1502
2100	1516	1515
2700	1537	1534
3300	1561	1554
3700	1575	1567
4300	1592	1586
4700	1606	1598

TABLE 2.

Variation of Speed of Sound in Sea Water with Temperature.

At the Surface. Salinity, 35 parts per 1000. Temperatures are in degrees Centigrade; speeds, in meters per second.

Temperature	Speed Heck and Service.	Speed British Admiralty.
0	1450	1445
5	1470	1467
10	1490	1487
15	1507	1504
20	1522	1519
22	1529	1524
24	1535	1529
26	1539	1534
28	1542	1539
30	1547	1543

TABLE 3.

Variation of Speed of Sound in Sea Water with Salinity.

At the surface. Temperature, 0° C. Salinities are in parts per 1000; speeds, in meters per second.

Salinity.	Speed Heck and Service.	Speed British Admiralty.
31	1445	1440
32	1446	1442
33	1448	1443
34	1449	1444
35	1450	1445
36	1451	1447
37	1452	1448

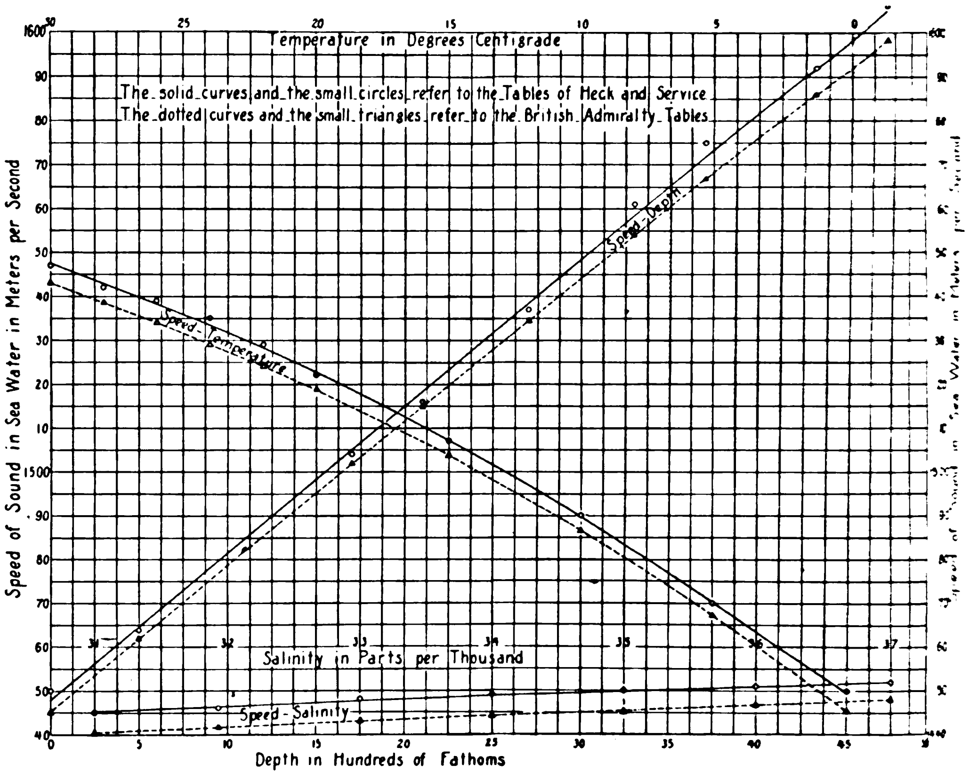
3. Speed increases very slowly with salinity, the total increase from 31 parts per thousand to 37 parts per thousand being only about 0.7 of one per cent., roughly about 0.1 of one per cent. for each part per thousand.

BRITISH ADMIRALTY TABLES OF THE SPEED OF SOUND IN SEA WATER COMPARISON WITH THE TABLES OF HECK AND SERVICE.

In 1927 the British Admiralty [4] published an excellent and very complete set of tables of the speed of sound in water, which were computed and prepared by Mr. D. J. Mathews on the basis of Newton's equation from the same elasticity and density data as were used by Heck and Service. Mr. Mathews, however, used Ekman's elasticity data directly,

thus avoiding small errors due to the method of computation to which the tables of Heck and Service are liable. Tables 1, 2 and 3 and Fig. 1, which show a fair selection of corresponding values of Heck and Service and of the British Admiralty, indicate the order of magnitude of those small errors. The

FIG. 1.



British Admiralty tables are free from tabular irregularities, as shown by the dotted curves of Fig. 1, and as might be expected. The maximum discrepancy between the two sets of tables is about 8 meters per second, or about 0.5 of one per cent. The British Admiralty speeds are systematically lower than those of Heck and Service by about 4 meters, or about one-fourth of one per cent. due simply to the difference in the methods of computation. It must be remembered that these

differences are of the same order as the probable errors in the speeds due to the probable errors of the very excellent experimental data of Ekman.

From the standpoint of convenience for echo sounding work, where the soundings are taken in fathoms the tables of Heck and Service including the application of the adiabatic correction involve less computation in their use than do those of the British Admiralty. For echo sounding work where the soundings are taken in meters and for radio-acoustic ranging where distances are required in meters, the British Admiralty tables involve very little, if any, more computation than do the tables of Heck and Service.

TABLE 4.

Comparison of the Results of Precise Measurements of the Speed of Sound in Sea Water with the Corresponding Values in the Tables of Heck and Service and of the British Admiralty, Respectively.

All measurements were made in comparatively shallow water.

Experimenter.	Temperature deg. Cent.	Salinity parts per 1000.	Measured Speed m/sec.	Speed Heck and Service m/sec.	Speed British Admiralty m/sec.
Stephenson [6]	−0.3	33.5	1,453	1,449	1,442.2
Marti [7]	15	32.3	1,504.15	1,503	1,500.9
Wood, Browne, Cochrane[8]	6	35	1,474.0	1,474	1,472.0
Wood, Browne, Cochrane[8]	7	35	1,477.3	1,478	1,476.1
Wood, Browne, Cochrane[8]	16.95	35	1,510.4	1,514	1,510.4
Eckhardt [13] See Note	13	33.5	1,492.3	1,498	1,495.5

Note.—The author took part in Eckhardt's measurements of speed and knows his measurements to have been of very great precision indeed. The distance was about 100,000 meters. Unfortunately, however, inadequate temperature observations were made over the range between bombs and hydrophones, so that his temperature as given above is perhaps a little higher than the true mean value between surface and bottom over the whole range.

The British Admiralty has rendered a great service to navigators by its Table 1 in which are given sound speeds to be used in echo soundings in various ocean areas. The navigator is not in a position either to measure or to search out in the literature the temperature and salinity conditions obtaining at various depths in the regions where he may wish to take echo soundings. Tables should be prepared for his

use giving him the correct speed of sound to use for a sounding of approximately a given depth in a given ocean area. This the British Admiralty has done in its Table 1. Heck and Service have published [5] convenient data of this kind for the whole Pacific Ocean.

A further comparative test of the tables of Heck and Service with those of the British Admiralty can be made by checking both against the results of precise measurements of the speed of sound in sea water under known conditions of temperature and salinity. Such a test is applied in Table 4.

MEASUREMENTS OF THE SPEED OF SOUND IN SEA WATER BY THE GERMAN SURVEY AND RESEARCH SHIP METEOR.

The German Atlantic Expedition has, upon some 250 stations occupied by the Survey and Research Ship *Meteor*, obtained simultaneous pressure soundings, echo soundings and serial temperature and salinity measurements. These 250 stations are distributed from the Antarctic Ocean through the tropics into the North Atlantic Ocean. Since the simultaneous pressure and echo soundings give the depth and the time of return of the echo, together they constitute a measurement of the speed of sound in sea water corresponding to known conditions of pressure, temperature and salinity. It is to be expected that when this wealth of material has been worked up an important contribution will be made to the knowledge of the speed of sound in sea water.[9]

TESTS OF THE TABLES OF HECK AND SERVICE BY PIANO WIRE AND ECHO SOUNDINGS BY THE U. S. COAST AND GEODETIC SURVEY.

Heck and Service checked [1] their tables against simultaneous piano wire and echo soundings on 44 stations occupied by the Survey Ship *Guide* on an oceanographic cruise. The temperature and salinity conditions on these 44 stations were fairly well known by means of serial temperature and salinity observations made by the *Guide*. They found an average percentage difference between the speeds from their tables, without the adiabatic corrections, and the measured speeds, of 0.2 of one per cent. The author has repeated this comparison, applying the adiabatic corrections, and has found that the effect of the corrections is to reduce the average percentage difference between the measured speeds and those from the

tables to *zero*, although as before there were individual discrepancies as great as 3.4 per cent. between measured and computed speeds.

Lieutenant E. W. Eickelberg, U. S. Coast and Geodetic Survey, in connection with the test of the fathometer that he installed on board the Survey Ship *Discoverer*, made a rather large number of simultaneous piano wire and echo soundings in the Pacific Ocean near the Hawaiian Islands. A considerable number of serial temperature observations were taken; also the salinity was fairly well known. He found that when he computed his echo soundings by speeds from the tables of Heck and Service, the echo sounding practically never differed from the piano wire sounding by more than one per cent., which included errors of observation in both soundings, errors of observation of temperature and the error of slope of the echo sounding.

DETERMINATION OF SOUND SPEEDS FOR ECHO SOUNDING IN THE U. S. COAST AND GEODETIC SURVEY.

Instructions for echo sounding in the U. S. Coast and Geodetic Survey require the hydrographer to take serial temperatures in the area to be surveyed, with the vertical interval such that the change of temperature between successive layers shall not exceed one degree Centigrade and with spacing of serial temperatures over the area such that the weighted mean temperatures from adjacent stations shall not differ by more than one degree Centigrade. These temperature observations are checked from time to time during a working season to detect any seasonal change should one occur that is of practical importance.

The author [10] has worked up simple procedure for the measurement of salinity of sea water: (1) by hydrometer; (2) by titration with silver nitrate with potassium chromate as indicator; and (3) by the dipping refractometer. Any of these methods can be used on board a vessel under way to give salinity, even in inexperienced hands, with an uncertainty not greater than 2 or 3 in the third significant figure. The hydrographer is required to make salinity measurements at such vertical intervals and with such spacing over the area that he will be sure of the second figure of salinity in any layer in any part of the area.

By means of the temperature and salinity data so obtained and the speed of sound tables of Heck and Service, the hydrographer can easily work up the values of speed of sound in convenient layers in the various sections of the area. The speed to be used in sounding to a given depth in a given section of the area is then the weighted mean of the layer speeds down to that depth.

DETERMINATION OF SOUND SPEEDS FOR RADIO-ACOUSTIC POSITION FINDING IN THE U. S. COAST AND GEODETIC SURVEY.

In the Coast and Geodetic Survey up to the present time, sound speeds for use in radio-acoustic position finding [11] have been determined almost exclusively by direct measurement. The ship, while within range of visibility of shore objects, fires a bomb in the water alongside and at the same time fixes its position by means of angles between shore objects measured on board the ship with sextants. The radio-acoustic apparatus measures the time of sound travel from the ship to the hydrophone at each of the shore stations. The positions of these hydrophones are plotted on the hydrographic sheet so that as soon as the ship's position has been plotted, the distance from the ship to each hydrophone can be scaled off. Thus two distances (usually only two stations are used) with the corresponding times of sound travel are obtained, which give two values of the speed of sound. It has been the practice of the Survey Ships in the past to use the mean of a large number of values of speed so measured during the season, for reducing and plotting all the radio-acoustic positions obtained by that ship during that season.

Since areas in which the ship's positions are fixed by the radio-acoustic method are usually sounded by the echo method, and since the temperature and salinity conditions in those areas would be therefore already determined as explained in the preceding section, it is the opinion of the writer that sound speeds for radio-acoustic position finding would be more accurately obtained from the tables of Heck and Service or of the British Admiralty rather than by direct measurement. The data presented in the next section, which is impartial, gives evidence that the probable errors of speeds taken from the tables would not be great, certainly no greater than

the errors inherent in the present practice. Furthermore, temperature and salinity conditions can be determined as far offshore as radio-acoustic positions are carried, while direct measurements of speed can be effected only within range of visibility of shore objects where generally the radio-acoustic method *will not be used;* the average physical conditions of the water over the ranges where the method *is used* will probably not be the same as those over the ranges where the speeds are measured.

TRANSMISSION OF SOUND IN RADIO-ACOUSTIC POSITION FINDING.

Early in 1925 the author had occasion to study speeds of sound measured as explained in the preceding section in 1924 by the *Guide* in the vicinity of Cape Blanco, Oregon, and to study the measured speeds in connection with temperatures measured by the *Guide* in the same area at about the same time for the Scripps Institution of Oceanography. The mean temperature over the straight line paths between bombs and hydrophones during the month of July was 11° C.; the salinity was 33 parts per thousand, very nearly. The mean measured value of speed was 1,473 meters per second. For the given conditions the tables of Heck and Service give a speed of 1,492 meters per second; *the discrepancy between this value and the measured value is considerably in excess of the combined possible errors of measured speed, measured temperature and the tables.* On the other hand, the *mean temperature between surface and bottom* over the area in which measurements of speed were made during July was 7° C.; the salinity was 33. The tables give for these conditions a speed of 1,475 meters per second, *which is in very fair agreement with the measured value, 1,473.*

The mean measured value of speed in October was 1,493 meters per second. The mean temperature from surface to bottom was 11° C.; the mean salinity was 33. For these conditions the tables give a speed of 1,491 meters per second, which also agrees very fairly with the measured value. Unfortunately no serial temperature observations were made during August or September.

This correspondence between speed of sound directly measured for horizontal transmission and the mean effective pressure,

temperature and salinity between surface and bottom over the range between bomb and hydrophone was independently discovered by the writer in the spring of 1925 and was announced to the Commanding Officer of the *Pioneer* through the Commanding Officer of the *Guide* in a letter written at San Pedro, California, on March 7, 1925.

The author at that time proposed (in the above-mentioned letter) the following hypothesis as to the mechanism of horizontal sound transmission, with which hypothesis, it is well to state frankly, many of his superior officers and associates disagree: that the sound energy from the bomb makes its way to the hydrophone principally by multiple reflections between surface and bottom*; whatever may precede it, the peak value of power received at the hydrophone, the peak that sets into operation the automatic transmitter [11] of the radio-acoustic apparatus, comes from bomb to hydrophone by way of all the horizontal layers of water between bomb and hydrophone; since the loss of energy by reflection increases as the incident and reflected wave fronts approach parallelism with the reflecting surface, the effective sound energy is propagated by very oblique reflections, so that the total length of path is not appreciably in excess of the distance measured along the surface from bomb to hydrophone; if the water between bomb and hydrophone is deep, fewer reflections and less loss of energy by reflection will occur than if the water is shoal, that is, a given quantity of sound energy released by a sound source can be transmitted practically to greater distances in deep water than in shoal water. In other words, the surface and bottom form a great two-walled speaking tube; as in any speaking tube if the walls are too close together so that the tube has too small a cross sectional area transmission will not be efficient. Upon this hypothesis it would be expected that sound could be transmitted to greater distances when the surface of the sea is smooth, other conditions being equal, than in rough weather; such seems to be the case. Likewise, the distance to which sound could be transmitted would depend upon the material and configuration of the bottom; the

* In shoal water, such as off North Carolina and Florida, evidently this must be the case because the straight line between bomb and hydrophone passes below the surface by a distance exceeding the depth of water.

author is not prepared to present evidence of the effect of the bottom material upon the transmission of sound in radio-acoustic position finding, but in the following are described two cases where it is believed that the failure of the radio-acoustic method can be attributed to a peculiar configuration of the bottom.

Professor Cole has, in this connection, reminded the writer of some early measurements of the speed of sound in air that were carried out in the water mains of Paris, where the speed was found to be a function of the diameter of the pipe, being greater for the larger pipes. This work was done by Regnault in 1862–63.[17] Regnault found also that the decrease of intensity with distance was greater, the less the diameter of the pipe. The writer would suggest that the two effects are probably closely related, for in sea water, at least, the speed increases with intensity, as pointed out in the last section of this dissertation. How could either effect be explained if transmission by multiple reflections between the walls be not assumed?

Dr. Earhart has reminded the author that the case of multiple reflections between surface and bottom is not quite analogous to the experiments of Regnault, because when the sound is reflected from the under surface of the water a change of phase of 180° occurs, where in the multiple reflections between the inner walls of the pipe no phase change occurs.

It had been found in the summer of 1924 that sound could not be transmitted appreciably across a submerged bank, steep on the seaward (bomb) side, located a few miles northwest from Cape Blanco, Oregon, although the crest of this bank was far below the straight line paths between bombs and hydrophones. This phenomenon was cited by the writer in his letter above mentioned in support of his hypothesis. For by his hypothesis a great part of the energy from the bomb would be reflected from the seaward side of the bank at nearly normal incidence with resulting great loss by reflection; in fact some of the energy would be reflected backward and wholly lost.

In like manner, it was found that no appreciable sound energy could be transmitted across Cortez Bank or Tanner Bank, off the coast of southern California, in the work of the *Guide* in the winter and spring of 1925, although the banks did

not intercept the straight line paths between bombs and hydrophones. These banks are extremely steep on the sides away from San Clemente Island, where the hydrophones were located.

Here Dr. Earhart suggests that if the theory of transmission proposed is correct and the effect on transmission from deep water to a bank is a fact, then the attenuation would be different according to whether the sound travels across the bank toward the shore or away from shore, and that this difference of attenuation might be capable of experimental verification.

In 1926 the *Guide* and *Pioneer*, working in adjacent areas north and south, respectively, of the mouth of the Columbia River, made a large number of measurements of the speed of sound in sea water for use in plotting the season's radio-acoustic positions. Unfortunately, not enough temperature and salinity data is available for the *Pioneer's* area to make her measurements of value for this study. The same is true of the *Guide's* area so far as measurements made in connection with her northern station (Westport, Washington) are concerned; but the area involved in measurements made in connection with her southern station at North Head, although the temperature and salinity data even here are inadequate, is fairly well represented by well-distributed temperature and salinity measurements made by the *Guide*. These serial observations yield a mean effective temperature from surface to bottom over the area covered by the measurements, of 6° C., and a corresponding salinity of 33 parts per thousand. The tables of Heck and Service give for these conditions a speed of 1,471 meters per second. The mean of the measured speeds was 1,469 meters per second. This very fair agreement is cited as further evidence in favor of the author's hypothesis as to the manner of transmission of the peak of power from bomb to hydrophone (giving due consideration to the fact that the temperature and salinity data are not adequate), because the temperature and salinity along the straight line path were approximately 13° C. and 33 parts per thousand, respectively, and the tables of Heck and Service for these conditions give a speed of 1,498 meters per second. The great discrepancy between this latter value and the mean measured value is far in

excess of the combined probable errors of the speed and temperature measurements and the speed tables.

It is evident that on the author's hypothesis the rate of decrease of intensity with increasing distance from the source will be less, and the range of a given hydrophone will be greater than on the assumption that the hydrophone is actuated solely by sound energy that follows the straight line path; for the intensity (on the author's hypothesis) will be more nearly proportional to the inverse first power than to the inverse square of distance.

The author wishes to state that he has advanced the above explanation merely as an hypothesis that seems consistent with such experimental data as are at hand. It does not appear to be inconsistent with any physical principles. It seems probable to the author, who has listened during several years to echoes from the ocean bottom, and who realizes that the bottom is a better reflector of sound, even at perpendicular incidence, than is generally supposed.

At the same time, the important thing in the preceding part of this section is not this hypothesis, but the experimentally verified correspondence of the speed of sound with the mean physical conditions between surface and bottom, and the effect of submerged banks upon the horizontal transmission of sound energy. The hypothesis may or may not be correct; the author will be ready to discard it when he is convinced that it is untenable, or when a more probable explanation comes to his attention. But the correspondence between speed and mean conditions has at least a considerable mass of experimental data in its support.

If the above hypothesis has no other virtue, it has justified its existence by the wealth of constructive criticism that it has evoked from the author's professors at the Ohio State University. Professor Cole has advanced an alternative explanation; Dr. F. C. Blake has introduced the author to Aigner's excellent treatise "Unterwasserschalltechnik," and Aigner verifies Professor Cole's explanation; Dr. R. F. Earhart has advanced a second alternative explanation. It is quite possible that after further reflection and calculation based upon these new ideas, the author may reject his multiple

reflection hypothesis altogether or at least modify it very radically.

Professor Cole has suggested independently that although the usual temperature gradient has the effect of refracting the direction of propagation downward (because the speed is greater in warm water than in cold), nevertheless in deep water the increase of speed with increasing pressure may well more than neutralize the temperature effect, so that the sound energy may follow a path through nearly all the layers between surface and bottom and yet be deflected upward toward the surface without reaching the bottom at all.

Aigner [20] has proved by calculation that the above explanation made independently by Professor Cole is feasible. His German is so excellent that the author is unwilling to spoil it by translation and therefore quotes it verbatim.

" . . . ist letztere (die Kompressibilitätskoeffizientenänderung) bei Wasser von 0° C. bei einer Druckzunahme auf 200 Atmosphären (corresponding to an increase of depth of about 1000 fathoms) ebenso groß wie bei einer Temperatursteigerung von 0° auf 20° C. Da aber diese beiden Effekte hinsichtlich der Schallgeschwindigkeitsänderungen einander entgegenarbeiten, falls die Temperaturschichtung anotherm ist, so folgt daraus, daß in diesem Falle bei einer durchschnittlichen Wassertiefe von 2 km eine Kompensation eintritt, somit auch im Sommer der schädliche Temperatureinfluß nicht zur Geltung kommt. In noch tieferen Gewässern findet bei gleicher Temperatur-Differenz un -Richtung sogar eine Ablenkung der Schallstrahlen gegen die Wasseroberfläche zu statt. Es ist daher zu erwarten, daß in Gewässern, in denen der schädliche Temperatureinfluß durch eine entsprechende Wassertiefe mindestens kompensiert wird, Reichweiten von einigen tausend Kilometern mit unverhältnismäßig kleinem Strahlungsleistungen zu erziehlen sind. Es entbehrt dabei die Ueberlegung nicht eines besonderen Reizes, daß eine Depesche über eine Strecke von 1,500 km ca. eine Viertelstunde benötigt, bis sich die akustische Energie von der Sendestation durch das wogende Weltmeer zur Empfangsstation durchgearbeitet hat. Leider liegen diesbezüglich bis heute keinerlei systematische Messungen im tiefen Ozean vor."

The author would suggest that when the source is below the region of high temperature gradient, as it can well be in radio-acoustic position finding, the effective range will be greater, according to Professor Cole's hypothesis as confirmed by Aigner, because then no downward refraction but rather upward refraction will occur in the early part of the travel.

Dr. R. F. Earhart rejects the author's multiple reflection hypothesis entirely. He makes an alternative suggestion as to the mechanism of transmission that has much to commend it, and which it seems well to include here. His suggestion is that as the wave advances the mechanical drag of the bottom upon the longitudinal vibrations of the particles "tips over" the waves much as water waves are tipped over and broken when they advance into the shoal water near the beach. As the waves are tipped over they are caused to strike the bottom and are absorbed, the effect being much the same as when sound is propagated against the wind in air. The effect will be relatively greater in shoal water than in deep, so that the effective range of a given source will be less in shoal water than in deep water, as is in accord with experience. The speed of propagation would be determined, so he states, by the mean effective physical conditions between surface and bottom, which is also in accord with experience.

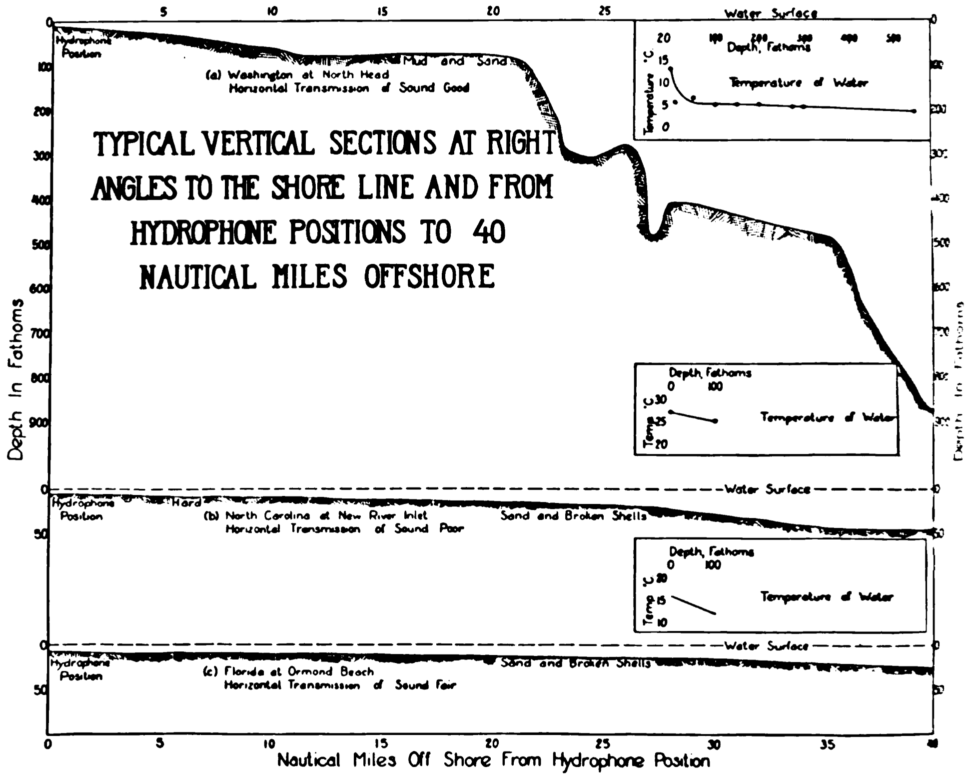
EXPERIENCE WITH RADIO-ACOUSTIC POSITION FINDING[11] IN VARIOUS REGIONS.

(a) In the Waters off Washington and Oregon.

In July, 1925, the writer planted hydrophones and laid hydrophone cables for the *Guide* at Port Orford, Hunter's Cove and Brookings, Oregon. These were the first shielded hydrophones used by the Coast and Geodetic Survey. The shielding was done under the direction of the writer and grew out of his study of the work of Brillié, as discussed in a later section of this dissertation. During the month of August, 1925, the *Guide* made a test run, steaming directly offshore from the Hunter's Cove station and firing a bomb in the water near the ship about once every half hour. A type of bomb designed by the writer, consisting of a hollow cast iron sphere of five inches inside diameter and one-half inch wall thickness, packed with loose TNT in which was imbedded a fulminate detonator with waterproof fuse, was found to be

most effective. Positions were obtained consistently with these bombs from the Port Orford and Hunter's Cove stations until the ship was more than two hundred (200) statute miles offshore and approximately that distance from each of the

FIG. 2.



two stations. At that distance the ship got out of range of the shore station radio transmitters; the limit of the range of sound transmission had not yet been reached. For some reason not well understood no appreciable energy from the bombs reached the hydrophone at Brookings. This remarkably successful run proved the practicability of the radio-acoustic method of controlling the momevents of a survey vessel on survey duty, at least in the waters off the Oregon and Washington coasts, and marked the beginning of the successful practical use of the method in those waters.

As an example of the practical use of radio-acoustic position finding in the waters off the coasts of Washington and Oregon, it may be stated that in 1926 the *Guide* surveyed the area between latitudes 46° 10′ N. and 47° 00′ N., from about 4 nautical miles offshore to about 70 nautical miles offshore. The positions of soundings in all parts of the area were fixed by the radio-acoustic method. Two shore stations were used, one near Westport, Washington, and one near North Head, Washington. It will be seen that the stations were located near the two inshore corners of the surveyed area; hence, when the ship was at either of the two offshore corners of the area, one of the two hydrophones was receiving sound energy from bombs fired from 75 to 80 nautical miles away. This may be described as good transmission.

The physical conditions in this area are shown in Fig. 2 (*a*), which represents a vertical section at right angles to the shore line from the hydrophone at North Head to 40 nautical miles offshore. The water temperatures are shown in the inset; the temperature gradient is seen to be rather great in the upper layers. The bottom materials probably are not very good reflectors of sound.

(*b*) In the Waters off North Carolina.

During the fall and winter of 1926–27 the *Lydonia* carried on experiments with radio-acoustic position finding off the coast of North Carolina between Capes Fear and Lookout to test the practicability of the method in those waters. The author took part in this work. Sound transmission was so poor that it was decided that the method was not economical in that area. The indications were that even with the hydrophone planted several miles offshore expectation that the hydrophone would receive sufficient energy from bombs fired more than 25 nautical miles away was not justified.

In addition to the poor transmission, the hydrophone circuit was very frequently disturbed by strong strays, especially in the late winter and early spring, believed to be caused by the sounds emitted by fish of the "grunt" family. Had the sound transmission been good enough to make it worth while, these strays probably could have been filtered out. The writer has experimented to some extent with an

electrical filter for similar strays off the Florida coast during the past winter, and the indications were that the filter would remove the strays almost entirely without seriously attenuating the energy from the bombs.

Fig. 2 (*b*) shows the physical conditions in the North Carolina area; it represents a vertical section at right angles to the shore line from the hydrophone at New River Inlet to 40 nautical miles offshore. The vertical scale is twice that in Fig. 2 (*a*). The temperature conditions of the water are shown in the inset; the temperature gradient is seen to be small. The bottom materials in this area are believed to form a surface that is favorable for the efficient reflection of sound energy.

(*c*) In the Waters off Florida.

During the past winter (1927–28) the *Lydonia* has carried on experiments with radio-acoustic position finding off the coast of Florida between St. Augustine and Cape Canaveral. The writer took part in these experiments. Sound transmission was found to be apparently somewhat better than off the North Carolina coast, although Fig. 2 (*c*) shows that the vertical section of the water at right angles to the shore line is not materially different from that in North Carolina, nor are the bottom materials believed to form any better reflecting surface than do those of North Carolina. Very few temperature data had been obtained up to the time of preparation of this dissertation; the inset shows the temperature conditions according to this inadequate data. Surprising as it may seem, the water is considerably colder than that in North Carolina. The conclusions from the Florida work were that with the hydrophone two nautical miles or more offshore, it is safe to expect the hydrophone to receive sound energy from bombs fired within a radius of 30 to 35 miles; expectations of a greater range did not appear to be justified.

DISCUSSION OF RADIO-ACOUSTIC EXPERIENCE.

The writer will not presume to decide why the transmission of sound in radio-acoustic work is good to excellent off the coasts of Washington and Oregon and poor to fair off the coasts of North Carolina and Florida. It will be well to consider what seem to be the probable factors affecting sound

transmission. One of the writer's associates, for whose scientific attainments and judgments he has very great respect, believes that within reasonable limits of depth of water the deciding factor is that of temperature gradient. If the gradient is great from surface to bottom, with the temperature decreasing with depth, the sound energy will be refracted downward and the associate mentioned believes that in such circumstances sound transmission will be poor. The writer agrees that such temperature conditions would be disadvantageous, but does not believe that temperature gradient is the deciding factor.

It is held by some of the writer's associates on the basis of experience that within reasonable limits of other conditions cold water will transmit the sound more effectively than warm water. This belief apparently is supported by the fact that transmission seemed to be better on the Florida coast than on the North Carolina coast, and also by the tests carried out by the *Guide* in Long Island Sound in November, 1923,[1, 13] in which tests the writer took part. Assuming equal temperature gradients the writer confesses himself at a loss to understand why water of low mean effective temperature should transmit sound better than water of higher mean effective temperature. As a matter of fact Aigner[21] has shown that the viscosity absorption loss of sound energy in sea water is decidedly less in warm water than in cold.

If in a given area transmission is better in winter than in summer the writer believes that the better transmission is due to a smaller temperature gradient (the surface temperatures more nearly equaling the bottom temperatures than in summer) rather than to a lower mean effective temperature.

It should be stated that many more tests were made with the hydrophone two miles or more offshore in Florida than in North Carolina, where all such experiments were discouraged by the strays attributed to the "grunts." The author considers it quite possible that if the tests were carried out in North Carolina during a time of year when the "grunts" were not active and with the hydrophone two miles or more offshore, just as good results might be obtained as in Florida.

It is significant that in North Carolina and Florida the hydrophone had to be placed about two miles or more offshore

to get the maximum range. In Florida, with the hydrophone one-half nautical mile offshore the range was about five miles; when it was 1.45 nautical miles offshore its range was 20 to 25 miles; when it was 2.1 nautical miles offshore its range was about 35 miles; when it was 10 nautical miles offshore its range was no greater than at 2.1 miles off. The experience in North Carolina was similar in this respect. On the Washington and Oregon coasts, however, in general no such effect was noted; one of the best stations, that at Port Orford, Oregon. (see account above of 200-mile run) had the hydrophone planted about 200 yards offshore.

Some of the associates of the writer hold that the amount of solid matter in suspension in the water is an important factor in sound transmission, transmission being poor (they state) when there is much suspended matter. The author has no data on the relative amounts of suspended matter in the waters off Washington-Oregon, North Carolina and Florida.

The fact remains that the transmission off either Florida or North Carolina is not nearly so good as off Washington and Oregon. The writer admits that a considerable temperature gradient, with temperature decreasing from surface to bottom, is probably unfavorable for good horizontal sound transmission. He is not ready to admit that sound is transmitted more effectively in cold water than in warm, with equal gradients. Nor is he ready to admit that the amount of suspended solid matter in the water, within reasonable limits, is an important factor in sound transmission. Granting that the surface and bottom in North Carolina and Florida are probably better reflectors than those in Washington and Oregon, nevertheless on the basis of his hypothesis as to the manner of sound transmission in radio-acoustic work, the author believes that the sound transmission is better off the Washington and Oregon coasts principally because the bottom slopes off more rapidly from the shore line to seaward so that the average depth of water between bomb and hydrophone is always considerably greater than is the case off North Carolina and Florida. In this connection the writer will quote from his hypothesis as to the manner of sound transmission as stated earlier in this dissertation. "If the water between bomb and hydrophone is deep, fewer reflections and less loss

of energy by reflection will occur than if the water is shoal, that is, a given quantity of sound energy released by a sound source can be transmitted practically to greater distances in deep water than in shoal water."

The author and his associates are open minded in the matter and will welcome suggestions from physicists and others as to the probably important factors affecting the horizontal transmission of sound through sea water. (See page 791.)

PHENOMENA OBSERVED IN CONNECTION WITH RADIO-ACOUSTIC POSITION FINDING AND ECHO SOUNDING.

Shielding of the Hydrophone.

In the first three seasons (winter of 1924, summer and fall of 1924, winter of 1924–25) of radio-acoustic work in the Coast and Geodetic Survey, the hydrophones were mounted so as to be fully exposed to the water and the hydrophone circuit was at most times continually being disturbed by strays of moderate intensity. The writer took part in all of this work and taxed his ingenuity to the utmost in his efforts to eliminate this trouble, which was so serious that it raised serious doubts as to the practical value of the radio-acoustic method.

These strays, or "parasite noises," received the name of "water noises," because some of the associates of the writer believed that they were caused by the roar of the surf on the beach. The writer never held this opinion, but believed that the strays were due to subsurface water currents flowing over the exposed hydrophone; these currents, in addition to the action of the water itself, perhaps cause sand, bits of shell, etc., to strike the hydrophone. Also, the hydrophone current had been observed to "breathe," i.e., increase and decrease slowly in value, which the writer attributed to the periodic changes in the hydrostatic pressure at the hydrophone caused by the passage of surface waves.

It was suggested by Dr. E. A. Eckhardt that the hydrophone might well be shielded by enclosing it in a perforated metal case. This was tried and effected no appreciable improvement.

In reading "Mechanical Properties of Fluids," by Drysdale and others, the author came upon an account of the work of Brillié, in which the latter had found the acoustic resistance

of certain kinds of wood to be nearly equal to that of sea water. It occurred then to the writer that if the hydrophone be enclosed in a fairly large, watertight wooden case, as for example a keg, filled with sea water, sound would pass through the wood and reach the hydrophone without attenuation, while the hydrophone would be completely shielded from mechanical disturbances. Some preliminary experiments were conducted by the writer, assisted by Almon M. Vincent, Chief Wireless Operator of the *Guide*. These experiments, in which two matched hydrophones were used, one exposed and one sealed in a keg full of sea water, gave very encouraging results. The shielded hydrophone was quite as sensitive to *sound* as the exposed one; the exposed one was subject to strays as usual, while the shielded one was almost entirely free from such disturbances. At the Port Orford station mentioned above in connection with the 200-mile test run of August, 1925, a single hydrophone was used, sealed in the keg used in the preliminary experiments. At Hunter's Cove three hydrophones in parallel were sealed into an oak box made for the purpose. In the box made for the hydrophone at Brookings several one-half-inch holes were bored; it is perhaps significant that the hydrophone circuit at that station was disturbed by strays as usual.

Since that time all the radio-acoustic hydrophones used by the Coast and Geodetic Survey have been sealed into watertight wooden cases filled with sea water, with very beneficial results on the Pacific Coast. On the coast of North Carolina the hydrophone cases did not eliminate the bad strays, because these strays were *sound* and not mere mechanical disturbances.

The writer has made a study of Brillié's original paper.[14] It is shown that where sound passes successively through three media of acoustic resistances n, n_1, n_2, then if

$$r_1 = \frac{n_1}{n} \quad \text{and} \quad r_2 = \frac{n_2}{n_1},$$

$$\text{(1)} \quad \frac{\text{Energy transmitted}}{\text{Energy incident}} = \frac{4r_1r_2}{(r_1r_2 + 1)^2} \times \frac{1}{1 - \sin^2 a_1 \dfrac{(r_1^2 - 1)(r_2^2 - 1)}{(r_1r_2 + 1)^2}},$$

where

$$a_1 = 2\pi \frac{l_1}{L_1},$$

l_1 being the thickness of the second medium.

If $n = n_1 = n_2$ as when the first and third media are sea water and the second is a material having the same acoustic resistance as sea water, the expression on the right becomes equal to unity and the sound is transmitted without attenuation.

If a_1 is nearly zero, i.e., if the thickness of the second medium is sufficiently small relative to the wave-length of the sound, then, as Brillié points out, we may set $\sin^2 a_1$ equal to zero, and we have

$$\text{(2)} \qquad \frac{\text{Energy transmitted}}{\text{Energy incident}} = \frac{4r_1r_2}{(r_1r_2 + 1)^2} \frac{4\frac{n_2}{n}}{\left(\frac{n_2}{n} + 1\right)^2},$$

which is as though the second medium did not exist, i.e., we need not be so careful to have its acoustic resistance near to that of sea water.

It may be stated as a matter of experience that sound from TNT bombs fired under water passes without appreciable attenuation through wooden cases having wall thickness of from one to two inches of any available hard wood; the wave-length of the sound is not definite but probably ranges from about fifteen feet to greater lengths. On the other hand, Dr. Herbert Grove Dorsey, Senior Electrical Engineer of the Coast and Geodetic Survey, found that wooden planks four inches thick were scarcely penetrable by sound of wave-length about five feet.

As Brillié points out, if the thickness l_1 of the second medium is equal to an exact multiple of half wave-lengths, then $\sin^2 a_1$ will be equal to zero and Eq. (2) will apply. It has occurred to the writer that this principle may serve as a means of shielding ultra-sonic receivers from "parasite noises" or strays, where these are due to mechanical disturbances; the wave-lengths of ultra-sonic energy range from about one-twentieth to one-sixth of a foot, i.e., from a little more than

one-half inch to about two inches. In the *Hydrographic Review*, Vol. IV, No. 2, November, 1927, is given an account of a considerable amount of trouble being experienced in such a receiver due to "parasite noises." The writer would suggest that if it were feasible to shield this receiver by a case of which the wall thickness is very nearly an exact multiple of the wave-length, the "parasite noises," if due to mechanical causes, might be eliminated without appreciable attenuation of the ultra-sonic energy.

RELATIVE ATTENUATION WITH DISTANCE OF SOUNDS OF GREAT AND OF SMALL AMPLITUDES.

Stokes, Rayleigh and Hart have shown [15] that in the transmission of sound energy through air, sounds of great amplitude have a greater relative decrease of intensity with increasing distance from the source than do sounds of small amplitude. Experience with radio-acoustic position finding has given qualitative evidence of the same effect in sea water, as might be expected. For example, if the ship is within ten or fifteen miles of a given hydrophone a no. 8 blasting cap fired in the water near the ship will usually send plenty of energy to that hydrophone to trip the apparatus; apparently a five-inch, cast iron, TNT filled bomb, of the type described earlier in this dissertation will not deliver more than about twice as much power as the blasting cap to the given hydrophone. The indications are that there will certainly be a limit to the range of a given hydrophone that cannot be increased, no matter how large or powerful the source of sound; this is probably because the more powerful the source, the more rapidly does the amplitude of the waves originating from that source decrease with increasing distance from the source.

VARIATION OF SPEED WITH INTENSITY.

Early in 1925, the writer, under the direction of Lieutenant Commander Thomas J. Maher, U. S. Coast and Geodetic Survey, Commanding Officer of the *Guide*, experimented with recording on a chronograph tape the times of explosion of blasting caps fired just beneath the surface of the water and the times of return of the echoes from the bottom, as a means of measuring depth roughly in fairly deep water. In 200 to

400 fathoms of water the method gave rather good results. Several echoes were recorded from each explosion. *The interval between the explosion and the return of the first echo was roughly only about half of the intervals between successive echoes,* presumably because of the great intensity of the wave before the first reflection from the bottom. The intervals between successive echoes apparently were equal and gave the correct depth to a fair approximation.

This recalls the work of Threlfall and Adair.[19] Glazebrook [18] gives so good an account of this work that it seems well to quote him here verbatim.

"Threlfall and Adair published in 1889 their experiments on the speeds of sound-waves from explosions under water in Port Jackson harbour, Australia. Charges of gun cotton were used; the firing was electrical and gave a signal on a chronograph, on which also was recorded the instant when the sound reached an india rubber diaphragm immersed at the far station 150 meters of more distant. The normal speed for feeble sounds in water was calculated to be about 1,500 meters per second; the observed speed of the explosion wave from 9 oz. of gun cotton was 1,732 meters per second and from 64 oz. of gun cotton was 2.013 meters per second."

Reference has already been made to the work of Regnault, which indicated a similar effect in air (p. 20).

APPENDIX. A BRIEF DISCUSSION OF METHODS IN USE IN THE U. S. COAST AND GEODETIC SURVEY FOR THE MEASUREMENTS OF DEPTH OF WATER.

In comparatively rare cases very shoal depths are measured with poles. This method is necessarily limited to water that is not more than about 2 fathoms deep.

Depths of 15 to 20 fathoms and less can be sounded economically by means of the hand lead and line. The ship sounds to as near shore as considerations of safety will permit; the areas nearer shore than this are surveyed by power launches or pulling boats. When the hand lead and line is used by the ship she runs continuously at a speed of about 6 knots. Power launches and pulling boats sounding with hand lead and line operate at somewhat lower speeds. Soundings are taken at intervals of about a minute or less.

"Trolley sounding" is similar to hand lead sounding but can be carried economically to depths of about 30 or 35 fathoms. The lead is dropped from forward and the line becomes vertical with the lead on the bottom to the leadsman stationed aft. As in hand lead work the leadsman reads off the depth from marks on the line. The lead is hauled in ready to drop from forward again by a power reel located forward. As in hand lead sounding the ship runs continuously at a speed of about 6 knots; soundings are taken at intervals of about 1½ minutes.

"Wire soundings" are carried out by means of a heavy lead (in deep water a detachable "shot") lowered by stranded or solid steel piano wire wound on a drum. The wire passes around a carefully calibrated sheave, which measures the number of fathoms of wire run out with considerable precision. The wire is reeled in by power on board ship and by hand on board a small boat. The method is applicable to any depth. The ship or boat must be kept "dead in the water" during a wire sounding in order to keep the wire vertical. Since the development of acoustic sounding methods, wire soundings are used principally as checks on the accuracy of acoustic soundings and pressure tube soundings.

Pressure tube soundings are applicable to depths from about 15 fathoms to about 80 fathoms. The Rude-Fischer tube is used, in which enough water is forced into the tube through a capillary opening in the cap to compress the air in the tube to equilibrium with the hydrostatic pressure outside. The capillary opening becomes water sealed so that neither the air nor the entrapped water can escape. The quantity of water forced in is a measure of the depth to which the tube has been lowered. During pressure tube sounding the ship runs continuously at a speed of about 6 knots and soundings are taken at intervals of about one or two minutes. The wire sounding machine is used in pressure tube sounding, a short length of cotton or manila line is placed between the lead and the end of the wire, and the tube is secured to this line just above the lead. Acoustic sounding with the "fathometer" is more or less superseding pressure tube work.

The "fathometer" equipment, manufactured by the Submarine Signal Corporation, consists of: (1) an electrically

driven oscillator with its diaphragm outside the skin of the ship below the water line, for generating short powerful sound impulses; (2) a microphone mounted in a tank full of water in contact with the inside of the ship's plating below the water line, and connected through a filter and amplifier to a neon tube and head phones, for receiving echoes of the oscillator signals from the ocean bottom; and (3) a device for measuring the time of return of the echo, consisting of a disk rotating at known, uniform speed behind a translucent dial graduated in fathoms, about an axis through its center perpendicular to its plane, and having two radial slits with the neon tube behind one and a fixed white light behind the other. The oscillator is made to sound when the neon tube slit and the white light slit are in line with the zeros of their respective scales on the translucent dial. In depths less than about 150 or 200 fathoms the neon tube flashes when the return echo is received, and since oscillator signals are sounded at intervals of ¼ second the result is a flickering luminous red indicator pointing out the depth of water on the dial. In deep water the disk carrying the slits is made to rotate more slowly, the oscillator signals are made to sound at greater intervals, and it is necessary to note the position of the white slit on the dial when the echo is heard in the phones. With a large oscillator this "white light method" is applicable to the greatest known depths. The "red light method" is not yet used for survey work in depths less than about 15 fathoms.

The "sonic depth finder," according to the experience of the writer, is applicable for survey work in depths from about 80 fathoms to the greatest known depths. The method of producing the sound is exactly that used in the fathometer and the method of receiving the echo is essentially the same. The distinctive feature, developed by the U. S. Navy, is the method of measuring the time of return of the echo. The oscillator signals are sounded at regular, adjustable, measurable intervals. The length of this interval is adjusted until the echo returns at the same instant as the first, second or third succeeding oscillator signal is sounded. The time of return of the echo is then equal to, or a known whole multiple of, the interval between oscillator signals. The sonic depth finder is being superseded on board the ships of the U. S. Coast and Geodetic Survey by the fathometer.

Soundings taken by any method are all reduced to the same stage of the tide, usually mean low water or mean lower low water, and as stated elsewhere in this dissertation echo soundings are reduced to the speed of sound corresponding to the physical conditions of the water where and when the soundings are taken.

In some areas obstructions of small extent are likely to occur, such as pinnacle rocks for example, that are especially dangerous to navigation but are not likely to be discovered by the methods above discussed. In such areas the above methods are supplemented by dragging operations with the wire drag or sweep.[16]

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Fighting Fires and Preventing Dust Explosions with Flue Gas —U. S. Department of Agriculture, Press Service. The use of inert gas, or flue gas, piped from the furnaces of manufacturing plants for use in preventing fires and resultant dust explosions in grinding equipment should be seriously considered wherever the hazard exists, according to engineers of the Bureau of Chemistry and Soils.

Of 30 explosions occurring in feed-grinding plants during a 20-year period, 18 originated in the grinding equipment where it was impossible to prevent the formation of dust clouds or to eliminate sources of ignition. Experimental work by the department engineers has shown that it is practicable to use inert gas for flooding the inclosures of the grinding equipment and diluting the oxygen content to such a point that fires or explosions can not take place. The results of the investigation are described in Technical Bulletin 74-T, "The Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment," recently issued by the department.

Although the investigations were conducted in feed-grinding equipment, the results suggest many other possible uses for inert gas as a fire preventive. A modern development of this fire-extinguishing principle is the storage of compressed inert gas in tanks with distributing pipes which lead to the most likely sources of fire and quick-acting valves to release the gas. Such equipment has been used on ships and also in factories. A portable extinguisher consisting of a small tank of carbon dioxide under pressure has recently been placed on the market.

Inert gas, especially carbon dioxide, has many advantages over other fire-fighting mediums since it will not injure metals, fabrics, food products, or other perishable materials. Neither does it freeze or deteriorate, and as it does not conduct electricity it can be used to extinguish fires in electrical equipment. Carbon dioxide leaves no residue, which is a distinct advantage, since frequently the residue or damage caused by the extinguishing medium constitutes a greater part of the total loss. These advantages indicate a promising field for inert gas as a fire-fighting medium as well as for explosion prevention.

THE TIME LAG OF THE SPARK GAP.

BY

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It is well known [1] that under certain conditions a spark gap in air can be overvolted for a considerable time without a disruptive discharge taking place between its terminals, where by overvoltage is meant any voltage above the least voltage that will produce a disruptive discharge when applied for an indefinite period. If, however, ultraviolet light is allowed to fall upon the electrodes or if a sufficient number of ions are present in the gap, the discharge takes place immediately upon application of the overvoltage.[1,2] This time of overvoltage or, as it is usually called, the time lag of the spark gap is shortened by increasing the magnitude of the overvoltage and becomes extremely short when steep, high voltage wave-fronts strike the gap. Pedersen[2] has observed time lags of sphere gaps in air as short as 10^{-7} sec. and in needle gaps even 5.6×10^{-8} sec., while McEachron and Wade,[3] using the cathode ray oscillograph found the time lag of the needle gap to be of the order of magnitude of one micro second. A large number of observations with varying amounts of overvoltage have been made by various observers under a wide variety of experimental conditions but most of their results have not been beyond criticism [4] due to the unknown magnitude and distribution of the space charge formed as the result of the large difference in mobilities of positive and negative ions.

In the present work a new method of measuring the time lag is described and some of the lags for sparks in air at atmospheric pressure have been recorded. The field strength used ranged approximately from 60,000 volts per cm. to

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[1] Sir J. J. Thomson, "Conduction of Electricity through Gases," Cambridge University Press, 2d Edition, p. 431.

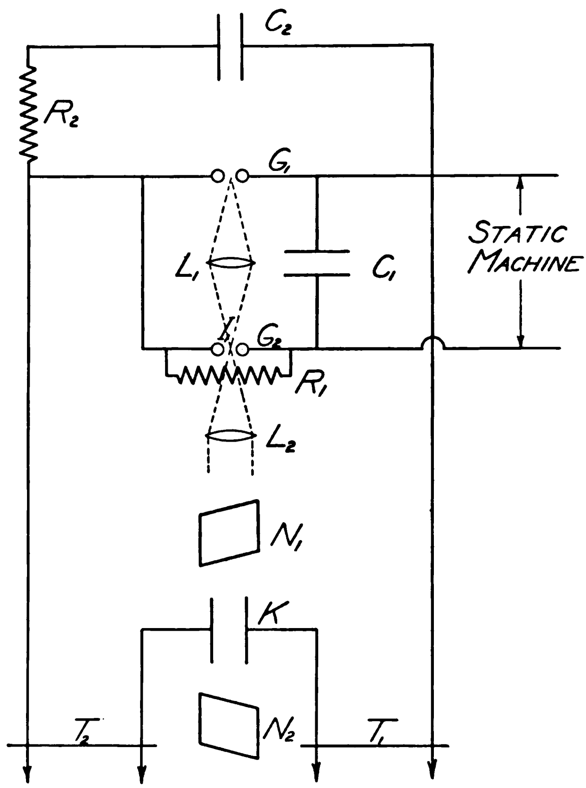
[2] P. O. Pedersen, *Ann. Der Physik*, 71, 317, 1923.

[3] McEachron and Wade, *General Electric Review*, 28, 622, 1925.

[4] Loeb, Journal of the Franklin Inst., 205, 305, 1928.

400,000 volts per cm. with as steep wave-fronts as could be obtained.[5] The method here used not only enables one to measure very short time lags which occur with high field strengths but the measuring device itself does not affect the results. This latter feature, as will be shown later, is of extreme importance if the results are to be of any value.

Fig. 1



The measuring instrument is a modification of that previously used [6] to measure the order of appearance of spectrum lines in sparks and condensed discharges and can best be described by referring to Fig. 1. The condenser, C_1, of .0015 microfarad capacity is slowly charged by a static machine.

[5] Lawrence and Beams, *Phys. Rev.*, 32, 478, 1928.

[6] Beams, *Phys. Rev.*, 28, 475, 1926.

This impresses a voltage across G_1 and G_2, which are two spark gaps in series but, due to the electrolytic resistance, R_1, of 10^5 ohms and comparatively small charging current, practically all of the potential is impressed across G_1. As the voltage across G_1 is slowly raised, a point is reached where the spark discharge takes place. This overvolts G_2, provided G_2 is smaller than G_1, since the steep wave-front cannot pass R_1 and the voltage wave probably is doubled by reflection at G_2. After a certain time (which is to be measured in these experiments) the gap G_2 discharges, the voltage across C_1 falls to zero and the process is repeated. If the time lag in G_2 is fairly long, as in some of the experiments, the spark discharge in G_1 stops before G_2 discharges and sets up harmful oscillations. Therefore a condenser C_2 of .001 microfarad capacity with 150 ohms in its leads was attached in parallel with G_1 to keep it ionized until the spark at G_2 started. Light from G_1 was brought to focus by lens L_1 at the point I_1, made parallel by the lens L_2 and passed through a Kerr cell containing CS_2 which was placed between crossed Nicols. The point I_1 is not in the gap G_2 but above it. Light from G_2 was raised almost to the same horizontal plane of I_1 by means of a right angled prism (not shown in the figure), made parallel by L_2 and then passed through the Nicols and Kerr cell so that in the field of view as seen through N_2, G_1 appeared just above G_2. The leads to the Kerr cell K were attached by copper wires T_1T_2 to opposite sides of G_1, these wires were of variable length and free as possible from loops and other influences that tend to increase their inductance.

As the potential builds up relatively slowly across G_1 it is also applied across K which becomes doubly refracting and light can pass N_2. If then G_1 discharges it has been found that none of its visible light, at least, passes N_2 provided of course that T_1T_2 are as short as possible and the intensity of the field in K is not too great. It is only when the field producing the double refraction is of such a value that the amount of light passing N_2 varies approximately as the fourth power of the field strength that the quick cut-off can be attained. By increasing symmetrically the length of T_1T_2 the light from G_1 first appears and then as T_1T_2 are still further increased the light from G_2 appears. If the length of wire

from G_1 to G_2 is equal to the difference in the light paths of G_1 to K and G_2 to K then the length of wire added to each lead from the first appearance of the light of G_1 until the first appearance of that of G_2 divided by the velocity of the electric impulse along the wire, is equal to the time lag of G_2. This assumes of course that the rate of increase of the light in G_2 is the same as in G_1, which is true to a very high degree of approximation since both gaps are in air and the amount of energy fed into G_1 by C_2 is very small during the initial stages of the discharge.

It should also be pointed out that it is necessary to observe the first appearance of the air lines in each spark because the fall of potential is almost coincident with the appearance of the air lines while the time between the appearance of the air lines and the metallic lines in single sparks depends somewhat upon the energy available for evaporation of the metal. The times between the appearance of the metal lines however are quite constant. The light from G_1 was carefully screened from G_2 and an air blast was directed between the terminals of G_2 so that the ions were removed between sparks. Care was taken to reduce the capacity of G_2 to a minimum by making the binding posts as small and as far apart as possible.

Since the time lags to be measured might be a function of such things as the steepness of the voltage wave which strikes it or the capacity of the gap these factors were investigated first. With, for example, 2 cm. brass balls in G_1 and G_2 and with those in G_1 3.5 mm. apart and those in G_2 2 mm. apart and the least inductance possible between G_1 and G_2, the time lag of G_2 was between 3 and 5×10^{-8} sec. Capacity was then added in parallel with G_2. A value of .00005 microfarad made the time lag greater than 10^{-7} sec. which with the particular arrangement used was the maximum lag that could be measured. This capacity was then removed and a few turns of wire added between G_1 and G_2 with another resultant increase in time lag. These observations serve to emphasize how important it is in this kind of work to reduce inductance and capacity to a minimum and suggests possible sources of error in other methods such as the capacity of the deflecting plates of the cathode ray oscillograph or large binding posts of the spark gap itself.

TABLE I.

For 2 cm. Brass Spheres in both G_1 and G_2.

Width of G_1 mm.	Width of G_2 mm.	Max. Time Lag 10^{-8} sec.	Minimum Time Lag 10^{-8} sec.
3.45	2.4	8.6	3.0
3.45	2.0	5.0	2.5
3.45	1.0	2.5	1.5

For Needle Gap, Radius of Curvature of .1 mm.

Width of G_1 mm.	Width of G_2 mm.	Max. Time Lag 10^{-8} sec.	Minimum Time Lag 10^{-8} sec.
3.45	7.5	10+	5.7
3.45	5.5	10	2.3
3.45	4.0	2.0	1.3
3.45	3.0	1.0	1.0−

Table I shows a typical set of observations for 2 cm. brass spheres in both G_1 and G_2 and when needles were substituted for the 2 cm. balls in G_2. It will be observed that as the gap G_2 is reduced and, therefore the voltage gradient raised, the time lag is decreased. It will also be noted that the time lag, especially at the lower field strengths, is not a definite magnitude but varies over a considerable range of values and in the needle gap the variation is greater than in the ball gap. When the field strength is increased the time lags become more definite and for the highest field strength used they become practically constant. This erratic behavior was at first thought to be due to factors in the circuit but a long series of tests and observations showed pretty definitely that the erratic behavior was not experimental error but the true nature of the spark lag itself.

It has long been known that in air at room temperature there is always a certain number of positive and negative ions continually formed by various natural agencies such as cosmic rays or radiations from radioactive materials. The electron when set free soon attaches itself to a molecule, or group of molecules, of oxygen or to the molecules of some electro-negative vapor that is always present unless the air is purified with considerable care. The positive ion wanders around until it picks up an electron which may either be free or part of a

negative ion. The number of ions usually present at any time is relatively small and distributed at random. The time lag of the gap here measured is then merely the time required for these ions under the impressed field to ionize the gap sufficiently for its resistance to drop to a small value.

In most of these experiments, since the voltage doubles at reflection and no special care was taken to insure clean smooth electrodes, the maximum field strength always reached the order of magnitude of 100,000 volts per cm. in some part of the gap. In these high fields an ion can reach a velocity several times the thermal velocity if allowance is made for the fact that a few of the free paths are longer than the mean. The negative ion therefore probably loses its electron in the first few collisions. This free electron is then in a position to readily ionize the gas and the discharge is started. The positive ion, with these high fields also contributes to the ionization and is especially effective in producing electrons near the cathode. The mobility of the positive ion is about 10^{-4} that of the electron. This effects a distribution of space charge which is very important in the fall of potential across the gap.

If we adopt the above rather crude picture of the phenomena taking place in the gap during the initial stages of the discharge, the erratic behavior of the lag is explained. In the case of both the sphere and the needle gap the field is not uniform over the whole volume between the electrodes and the ions are distributed at random. The rate of increase of ions is therefore not the same in different sparks which accounts for the fluctuations observed in the preceding experiments. In the needle gap although the field is very high near the point it drops very rapidly as the distance from the point is increased so that over the greater part of the gap the field strength is less than in the sphere gap. This should account for the greater fluctuations observed in the needle gap than in the ball gap. It would also explain in a qualitative way the observation that the fluctuations become less with increased voltage (decreasing width of gap). However it is difficult to see how the fluctuations can be reduced so much with the increase of voltage gradient and reduction of the size of gap alone.

It is now generally believed that there is a dense adsorbed

layer of molecules that covers the surface of electrodes in air. This idea was first proposed by Zeleny [7] to explain the discharge from pointed conductors and has since been used to interpret many phenomena in connection with the spark discharge. The molecular film may complicate the beginning of the discharge by offering a virtual resistance to positive ions that are formed near the cathode, thus rendering them less effective in ejecting electrons from the cathode until a critical velocity of the ion is reached. This may account, in part, for the short lags as well as the absence of fluctuations with high field strengths. However, from previous experiments on the nature of this film, one should expect the positeld ions to be able to puncture the molecular film at a lower fiive strength than that here used. On the other hand this film may make it easier for electrons to be "pulled out" of the cathode by the electric field than when the cathode is outgassed and in a vacuum. If this were true it could explain the very short lags and absence of fluctuations observed with high field strengths.

The writer is very much indebted to Professors L. G. Hoxton and C. M. Sparrow for many helpful discussions, to Mr. J. C. Street for taking some of the observations and to Mr. A. J. Weed, instrument maker, for constructing part of the apparatus.

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[7] J. Zeleny, *Phys. Rev.*, 3, 69, 1914. J. Zeleny, *Phys. Rev.*, 16, 102, 1920.

Chemical Warfare at Sea. LIEUT. HAROLD W. NORTHCUTT of the U. S. Navy (*Chemical Warfare*, 1928, *14*, 374–378) discusses chemical warfare and the ship of the line or battleship. The ship will not attempt to project gas. Its main battery must be used for the immediate destruction of enemy vessels by means of high explosive shells. The secondary battery and the anti-aircraft battery are required, respectively, to repel torpedo attack by destroyers and attack by airplanes; the time element prevents their use for offensive chemical warfare; also, chemicals are of little use against airplanes. The airplanes carried by battleships are intended for observation purposes and fire control, not for the projection of chemicals. Chemical torpedoes, as distinguished from heavy explosive torpedoes, have little value as offensive weapons.

From the viewpoint of defense against chemicals, should they be used by the enemy, gas masks and a properly designed ventilating system suffice to protect from gas shells, and toxic and obscuring smoke screens. No additional defense is required against chemical torpedoes. The only probable method of attack by gas is by planes from aircraft carriers, should the enemy have control of the air and succeed in avoiding the fire of the anti-aircraft battery. Smokes and toxic chemicals may then be dropped in bombs, or the chemicals may be sprayed from the plane. The defense against such an attack is a gas alarm, protective clothing, gas masks, and control of the ventilating and air-purifying and cooling systems to prevent the transmission of the gases through the ship. Additional armor protection is not required.

J. S. H.

Viscosity of Milk. GEORGE MONROE BATEMAN and PAUL FRANCIS SHARP of Cornell University (*Jour. Agric. Research*, 1928, *36*, 647–674) have studied the viscosity of milk. The viscosity may be influenced by various factors, such as clumping of the fat globules, mechanical agitation, homogenization, pasteurization, freezing and thawing, age of the sample, and chemical composition of the total solids. The viscosity of a sample of milk does not necessarily indicate accurately the total solids content, except possibly for very restricted groups of samples; and the viscosity determination alone can not be used as a test for small amounts of added water.

J. S. H.

QUENCHING OF MERCURY RESONANCE RADIATION AND ITS RELATION TO REACTIONS SENSITIZED BY EXCITED MERCURY ATOMS.

BY

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It has been shown that certain gaseous reactions proceed in the presence of optically excited mercury atoms which otherwise, under similar conditions of temperature and pressure, do not take place at all. Thus Cario and Franck [1] have shown that if a mixture of hydrogen and mercury vapor be placed in a quartz tube in the presence of copper oxide and radiated with light from a cooled quartz mercury arc a decrease in pressure occurs, corresponding to a reaction of the hydrogen with the copper oxide. On the other hand, if either one of the constituents hydrogen or mercury vapor is absent, or if all three constituents are present and the mercury arc is run hot, so that the center of the 2537 Å. line is reversed, the reaction does not proceed. A great number of other reactions have been shown to proceed under similar circumstances. Thus hydrogen may be made to react with oxygen,[2] ethylene, carbon monoxide and nitrous oxide [3] at room temperature; also ozone may be formed from oxygen in the presence of excited mercury atoms; [4] and ammonia [5] may be decomposed under similar circumstances. The first step in any of these reactions is obviously the absorption of the 2537 Å. resonance line of mercury by the mercury atoms in the mixture, causing them to be raised to the 2^3P_1 state, having 4.9 volts energy. These reactions have been called *sensitized reactions*, since the process is somewhat analogous to the sensitizing of photographic plates.

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[1] G. Cario and J. Franck, *Zs. f. Phys.*, **11**, 161 (1922).

[2] R. G. Dickinson, *Proc. Nat. Acad. Sci.*, **10**, 409 (1924).

[3] H. S. Taylor and A. L. Marshall, *J. Phys. Chem.*, **29**, 1140 (1925).

[4] R. G. Dickinson and M. S. Sherrill, *Proc. Nat. Acad. Sci.*, **12**, 175 (1926).

[5] R. G. Dickinson and A. C. G. Mitchell, ibid., **12**, 692 (1926).

It has generally been assumed that all of the activational processes occurring in these reactions take place in the gas phase and that none of these steps takes place on the walls of the vessel. Recently, however, it has been suggested by Zemansky,[6] on theoretical grounds, that all sensitized reactions are catalyzed by the wall of the reaction tube nearest the incoming light.

As far as the present writer is aware there are no direct experiments on reactions sensitized by mercury vapor in which the effect of varying the size and shape of the front wall of the reaction tube has been investigated. Indeed there are grave difficulties involved in carrying out such an experiment. However difficult the experiment, it would, as Zemansky suggests, be interesting if such an experiment were performed and gave a conclusive result. The purpose of this paper is to point out respects in which the author is unable to concur in Zemansky's argument and to recall, in connection with sensitized reactions, some already well known facts, derived from a neighboring field, which lead us to believe that sensitized reactions are homogeneous gas-phase reactions. The author rather hesitates to present facts that have been known for a number of years, but since there are some who may not have these facts available and since a full presentation of the facts leads to greater clarity of thought, they will be presented here as briefly as possible.

It has been shown by Stuart [7] that the gases O_2, H_2, CO_2, CO, H_2O, N_2, A, and He can quench the resonance radiation of mercury. The experiment was carried out by illuminating mercury vapor in a resonance bulb with the center of the line 2537 Å. (obtained by using a "resonance lamp") and measuring the intensity of the resonance radiation emitted from the bulb both when it contained no foreign gas and when there was a definite pressure of foreign gas present. It was found that the intensity of the resonance radiation decreased as the pressure of the foreign gas increased and curves connecting the intensity of resonance radiation with the pressure of the added gas were plotted. Further, the gases N_2, A, and He quenched but slightly whereas the other gases, especially H_2,

[6] M. W. Zemansky, *Phys. Rev.*, **31**, 812 (1928).

[7] H. A. Stuart, *Zs. f. Phys.*, **32**, 262 (1925).

O_2, and CO, showed a considerably greater effect. Since the former three gases have no excitation potentials below 4.9 volts it was thought that they transfer excited mercury atoms from the 2^3P_1 state to the *metastabile* 2^3P_0 *state* (4.7 volts) while the rest of the energy goes into relative kinetic energy of the two atoms.[8] This has been actually shown to be the case by the experiments of Wood,[9] Donat [10] and Loria.[11]

Now, there is a theorem by Stern and Volmer [12] which may be applied to the quenching of resonance radiation. It states that if there exists a mixture of excited atoms which may either radiate or lose their energy of activation by collision with molecules of foreign gas (or unexcited atoms of their own sort), then at a pressure of foreign gas at which the intensity of resonance radiation is reduced to half its value when no foreign gas is present, the time between collisions is equal to the mean life, τ, of the activating atom in the excited state. The theorem takes no cognizance of imprisoned radiation nor does it, in the form in which Stuart applied it, consider cases in which excited atoms are being formed by any other mechanism besides absorption of radiation; it further assumes every collision between an excited atom and a foreign gas molecule leads to quenching. Table I gives the half-value pressures as given by Stuart. On applying the Stern-Volmer theorem to these data, it will be seen that if we assign a given radius to the excited mercury atom and make use of the kinetic theory diameter for the other molecules in question, we will have to make use of an efficiency factor, η, which allows for the fact that not all collisions between excited atoms and foreign molecules lead to quenching. One would like to take the quenching efficiency of H_2 equal to 1, since it actually has the lowest half-value pressure and since it is known that it can take up 4.34 volts of energy from excited mercury atoms. Since, however, η is the number of quenching collisions per

[8] O. Oldenberg (*Zs. f. Phys.*, **49**, 609 (1928)) has shown that collisions between argon and excited mercury also lead to a transfer of the mercury atoms to the *normal* state without the emission of radiation.

[9] R. W. Wood, *Phil. Mag.*, **50**, 774 (1925).

[10] K. Donat, *Zs. f. Phys.*, **29**, 345 (1924).

[11] S. Loria, *Phys. Rev.*, **26**, 573 (1925).

[12] O. Stern and Volmer, *Phys. Z.*, **20**, 183 (1919).

collision, it turns out that η would assume a value greater than 1 in the case of O_2. Stuart therefore takes η for O_2 equal to 1, and, on assigning a collision radius for excited mercury (3.4 times the kinetic theory value), calculates the efficiency factors for the other gases. These are tabulated in Table I, for reference.

TABLE I.

(From Stuart.)

Gas.	Half-Value Pressure mm.	Time between Collisions at Half-Value Pressure.	Yield ($\eta \times 100$).
H_2.......	0.2	7.10^{-8}	70
O_2........	0.35	1.10^{-2}	100
CO.......	0.4	8.10^{-8}	80
CO_2......	2.0	2.10^{-8}	20
H_2O......	4.0	1.10^{-8}	10
N_2.......	30.	$1.3 \cdot 10^{-9}$	1.3
Ar.......	240.	2.10^{-10}	0.2
He.......	(760.)	3.10^{-11}	0.03
Air.......	1.2	—	—

Recently Stuart's treatment of his data has been criticized by Foote [13] and also by Zemansky.[6] Foote objects to representing the processes occurring in the quenching of resonance radiation as that presented by the Stern-Volmer theorem. He wishes to allow for imprisoned radiation, small amounts of impurities, and the fact that in the cases of N_2, A, and He excited mercury atoms may be formed from metastabile ones by collisions with fast gas molecules. By this latter mechanism he is able to explain away the efficiency factors for N_2, A,[14] and He, but the efficiency factors for the other gases O_2, CO, H_2O, etc. remain unexplained.

An alternative method of treatment is offered by Zemansky. By the use of Milne's theory of imprisoned radiation he is able to show that the number of collisions between mercury atoms in the 2^3P_1 state and foreign gas molecules which lead to quenching of the resonance radiation, is proportional to a fractional power of the pressure of the foreign gas. Thus on plotting the log of the number of quenching collisions

[13] P. D. Foote, *Phys. Rev.*, **30**, 288 (1927).

[14] This explanation is difficult to reconcile with the experiments of Oldenberg on argon, ref. 8, l.c.

against the log of the pressure he finds a straight line with a slope of about 0.5 (actually the slopes vary from 0.4 to 0.6). Since, now, some of these gases have been shown to react after collision with excited mercury atoms he makes the usual assumption that the number of quenching collisions is a measure of the rate of reaction [15] and arrives at the conclusion that the rate of reaction is proportional to a fractional power of the pressure. He takes this fact to mean that the reaction is a heterogeneous one [16] and proposes the following mechanism to account for the rate; (1) Mercury atoms are excited to the 2^3P_1 state by absorption of radiation; they may either (2) radiate, and the radiation eventually get out as resonance radiation, or (3) be transferred to the metastabile state by collisions with foreign gas molecules; (4) these metastabile atoms then diffuse to the front wall of the resonance vessel where (5) the foreign gas molecules actually obtain their energy of activation from them. This mechanism does not admit that foreign gas molecules may be activated by *excited* (2^3P_1) mercury atoms, nor does it allow that *metastabile* mercury atoms may lose their energy of activation to foreign gas molecules before reaching the wall. These two requirements are in contradiction to a number of well known facts as we will now proceed to show.

The most clear-cut of any chemical reaction sensitized by excited mercury atoms is that between hydrogen and copper oxide.[1] Turner [17] has shown, for this reaction, from kinetic theory considerations similar to those of Stern and Volmer, that a straight line can be obtained by plotting the reciprocal of the average reaction rate against the reciprocal of the average hydrogen pressure, and that the average life of a mercury atom in the excited state can be calculated from the ratio of the slope to the intercept of this line, if a suitable radius (2 to 3 times the

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[15] This supposes that the first step in the reaction is the rate determining step as is usually the case in reactions of this type.

[16] The fact that a reaction has a rate proportional to the ½ power of the pressure of one of the components does not necessarily mean that the reaction is heterogeneous. See, for example, Bodenstein and Lütkemeyer, *Zs. f. Phys. Chem.*, **114**, 208 (1925), where a chain mechanism is involved to explain the fact that a homogeneous gas phase reaction has a rate dependent on the ½ power of the pressure of one of the components.

[17] L. A. Turner, *Phys. Rev.*, **23**, 464 (1924).

kinetic theory value) be assumed for the excited mercury atom. This mechanism assumes that every collision between an excited mercury atom and a hydrogen molecule results in the activation of the hydrogen, a plausible assumption since the quenching efficiency of hydrogen is known to be high, and that the excited mercury atom reverts to the normal state. The good agreement between the accepted value of τ for the excited mercury atom and the value calculated from this theory could only be obtained if the activation of hydrogen by excited mercury atoms was a homogeneous gas-phase reaction.

Another piece of evidence for the homogeneity of sensitized reactions is to be found in the closely allied field of *sensitized fluorescence*. Franck [18] and his pupils have shown that if a mixture of mercury vapor and metallic atoms of a sort B, having one or more excitation potentials below 4.9 volts, be radiated by light from a cooled quartz mercury arc, the excited mercury atoms thus formed give up their energy of excitation to the B atoms, causing them to emit their characteristic radiation. They further showed that if the B atoms have an excitation potential K (below 4.9 volts) then the difference in energy, $\Delta e = 4.9 - K$, goes into the relative kinetic energy of the two atoms. The atom B, which now radiates, has a translational energy

$$u_B = \frac{\Delta e}{1 + \dfrac{m_B}{m_{\mathrm{Hg}}}}$$

volts and shows a corresponding Doppler broadening. This predicted Doppler shift has actually been observed and its magnitude found to agree quantitatively with that predicted from the theory given above. The reverse process has also been found to occur, namely, if the B atom has a resonance potential a little above 4.9 volts, then if the temperature is high enough, the relative kinetic energy of the two atoms as they come together may furnish enough energy so that a B atom, having an excitation potential of 6.3 volts

[18] For a summary of all the work that has been done in this field, see J. Franck and P. Jordan, "Anregung von Quantensprüngen durch Stösse," p. 216 et seq.

(Cd) may be excited,[19] although to a small extent. Such a state of affairs could hardly be expected if the process of sensitized fluorescence were taking place on the wall, as it is very probable that the wall would act as an energy reservoir and take up the excess energy, at any rate the quantitative agreement would not be provided for. Since sensitized reactions should obey the same laws it follows that the activational processes of these reactions take place in the gas phase.

It has also been shown from kinetic theory reasoning[20] that the probability of a collision of the second kind is greatest when the least energy is dissipated into kinetic energy. This has been verified by experiments[21] on the intensity of spectral lines emitted in sensitized fluorescence where it has been found that those lines emitted from a level having energy near 4.9 volts (in the case of mercury sensitization) have a greater intensity than other lines emitted from a level having energy greatly below 4.9 volts. If the process of sensitized fluorescence were taking place on the wall, one would expect as in the above argument that the wall would act as reservoir of energy and that no such correspondence between the intensity of the emitted spectral lines and the energy level from which they came.

The large quenching efficiency of O_2 has been a troublesome point to a number of investigators, for if it is admitted that the probability of a collision of the second kind is greatest when the least energy is dissipated into kinetic energy, it would be expected that H_2 would have the greatest quenching efficiency since it has a dissociation potential at 4.34 volts, it being known that the first electronic resonance potential as well as the dissociation potential of O_2 is well above 4.9 volts. Recently, however, a complete study of the band spectrum of O_2 has been made by Ossenbrüggen[22] who tabulates wave numbers from which the energy of the first seventeen oscillational levels of the (normal electronic) molecule may be obtained. The wave numbers of the band heads in O_2 may be

[19] Cario and Franck, *Zs. f. Phys.*, 17, 202 (1923).

[20] J. Franck and P. Jordan, "Anregung von Quantumspringen durch Stösse," pp. 211–212.

[21] Beutler and Josephy, *Naturwiss.*, 15, 540 (1927).

[22] W. Ossenbrüggen, *Zs. f. Phys.*, 49, 167 (1928).

represented by the equation

$$\nu_0(n'n) = 49{,}777.3 + [721.2(n' + \tfrac{1}{2}) - 13.3(n' + \tfrac{1}{2})^2] - [1576.74(n + \tfrac{1}{2}) - 11.37(n + \tfrac{1}{2})^2], \quad (1)$$

where n' is the oscillational quantum number of the molecule in the excited and n that of the normal electronic state. The vibrational frequency of the molecule in the normal electronic state is given by

$$\omega^n = \frac{\partial \nu_0}{\partial n} = (-)[1576.74 - 22.37(n + \tfrac{1}{2})]. \quad (2)$$

On plotting ω^n against n the first seventeen points lie on a straight line. Assuming, as do Birge and Sponer [23] that a linear extrapolation of these data may be made, we find that the line cuts the n axis at $n = 69.5$ and the heat of dissociation of O_2, calculated in the usual manner, is found to be about 6.6 volts. Therefore, O_2 must have oscillational levels corresponding to all the quantum numbers from $n = \frac{1}{2}$ to $n = 69.5$. By integration of $\int_{\frac{1}{2}}^{m+\frac{1}{2}} \omega^n dn$ from equation (2) the energy of the oscillational level which lies nearest to 4.9 volts, the excitation potential of the excited mercury atom, may be calculated and it is found that the energy of the oscillational level corresponding to $n = 33.5$ is 4.86 volts. If O_2 can take up this amount of oscillational energy by collision of the second kind with excited mercury atoms [24] then it is easy to account for the high quenching efficiency of O_2 since very little energy (0.04 volts) is dissipated into kinetic energy.

CONCLUSION.

1. Zemansky's treatment of the quenching of resonance radiation has been reviewed with conclusions unfavorable to the theory there proposed.

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[23] R. T. Birge and H. Sponer, *Phys. Rev.*, **28**, 259 (1926). Birge and Sponer had data at hand for the O_2 bands from which they could derive the oscillational levels for quantum numbers 11 to 17 and were able to calculate the heat of dissociation.

[24] Oldenberg (l.c.) has shown that CO and N_2 may take up oscillational energy from 2^3P_1 mercury atoms, transferring them to the metastabile 2^3P_0, state, thus accounting for the fact that CO and N_2 have higher quenching efficiencies than A and He.

2. The activational processes of sensitized reactions have been discussed and it has been pointed out that these processes most probably occur in the gas phase.

3. The high quenching efficiency of O_2 for mercury resonance radiation has been accounted for by assuming that O_2 can take up energy of oscillation by collision of the second kind with excited mercury atoms.

The Chemical Warfare School of Applied Chemistry at The Massachusetts Institute of Technology is described by CAPT. M. E. BARKER (*Chemical Warfare*, 1928, *14*, 372–373). This school is a graduate course covering two full calendar years. The preparatory subjects or professional prerequisites usually include calculus, chemical principles, and industrial stoichiometry. The required subjects include chemical engineering, differential equations, industrial organization, industrial chemistry, organic chemistry laboratory, advanced inorganic chemistry, powders and explosives, chemical engineering practice, and a research and thesis topic. The chemical engineering practice includes three periods of eight weeks each, spent, respectively, in heavy chemical manufacturing plants in Boston, the paper, pulp, and cellulose factories at Bangor, Maine, and the steel mills and by-product coke ovens at Buffalo, New York. The 8 or 10 electives, which must also be completed, are usually related to the subject of the thesis, and are selected from groups in organic chemistry, chemical engineering, and mechanical engineering.

J. S. H.

Spontaneous Ignition of Stable Manure. L. H. JAMES, G. L. BIDWELL, and R. S. MCKINNEY (*Jour. Agric. Research*, 1928, *36*, 481–485) report the repeated spontaneous ignition of a pile of heating stable manure. The pile was 200 feet long, 50 feet wide, and ranged from 1 foot to 20 feet in height. The center of the pile had a temperature of 51° to 66° C. The outer layers had a considerably higher temperature. As a rule, the highest temperature was within 6 inches of the surface where the the manure was tightly packed, and within 1.5 or 2 feet of the surface where the manure was loosely packed. At the surface, the smoking straw had a temperature of 76° C., the glowing straw a temperature of 132° C.

Introduction of oxygen into a section of the manure produced an increase of 26.5° C. in its temperature in 30 minutes. The temperature measurements were made by means of a potentiometer and a thermocouple which was introduced into the manure.

J. S. H.

THE EFFECT OF DARK SURROUNDINGS UPON VISION.

BY

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It has long been known that the sense of vision is at a disadvantage when trying to discern dimly lit objects in the midst of a brightly lit field. The attempt to see the interior of a building, by natural light from the outside, by looking in at an open window will exemplify such a situation; or the attempt, at night, to see outside objects from a well-lighted interior. The essential setting consists of a comparatively dark field, of limited size, surrounded by an extensive brightly-lighted area. Under the circumstances, casual observation soon convinces one that the objects within the dark area are more easily seen with the bright surroundings removed or darkened.

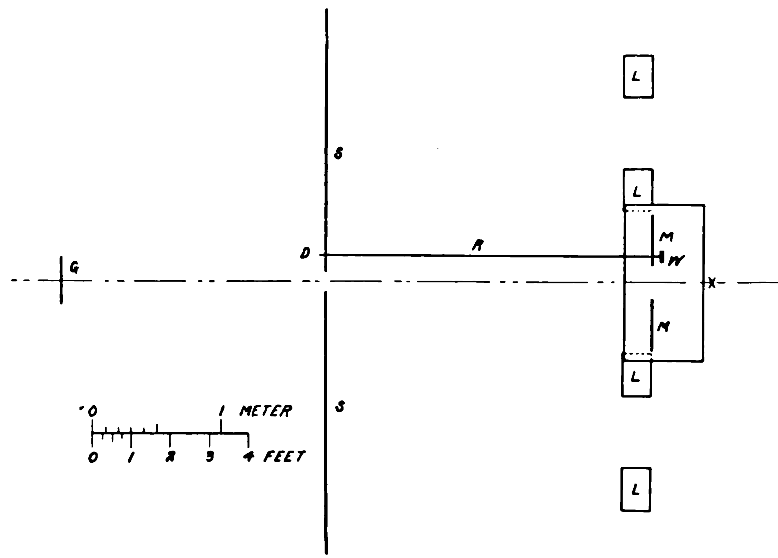
The reverse case, that of vision upon a bright field of limited size, set in relatively or absolutely dark surroundings, as in looking out of the window into the daylight, is one with respect to which the facts are less obvious. Some years ago, however, one of the authors [1] was able to show that in this situation also a certain temporary impairment of visibility is at hand, although of relatively small degree, and that the best condition for vision is one in which the brightness of the surroundings is about equal to that of the limited field upon which the eyes are called upon to work.

The conditions represented by the bright field set in darkness are of twofold importance. In experimental work in vision, it has often been the procedure to present the field to the eye by having the subject look into an eye-piece. Ordinarily, the field so seen will be surrounded by darkness; and the applicability of results so obtained to the usual

[1] Cobb, Percy W., "The Effect on Foveal Vision of Bright Surroundings." *Jour. Exp. Psychol.*, I, 1916, pp. 540–566.

conditions of vision on widespread bright fields is open to some doubt. A second situation of this description is that in which a person sits near a table-lamp, reading a highly illuminated page in a room which is otherwise dark, and in which therefore the paper presents a high-light. While economical of light, it is a question whether this situation facilitates vision to the best advantage.

FIG. 1.



General Plan of Apparatus. The subject sat at the table with his eyes at X, viewing a central portion of the screen S–S limited by the opening in the mask M–M. By means of the hand-wheel W and the rod R he was able to move the lower stylus to keep it in opposition to the upper one.

A question of critical interest in this connection is the angular distance to which the borders of the dark surroundings must be removed from the center of the visual field in order to abolish the adverse effect upon vision. In the experimental work cited, the bright working field was small and of rectangular shape, and its dimensions in the visual field, vertically and horizontally, were 2° and 2.6°, respectively. The work about to be described is an attempt to determine how far the borders of the dark surroundings would have to be removed from the line of direct vision (or how far the bright working-field would have to be extended) in order that visibility at the center should be at its best.

To provide such conditions, a large vertical white screen was erected near one end of a large room. This screen (*S–S*, Fig. 1) extended upward 2.44 meters (8 feet) from the floor, and was 4.26 m. (14 feet) wide. The subject sat at a table near the other end of the room, with his eyes (at *X*, Fig. 1) directly opposite the center of this screen and at 3 m. (9 feet, 10 inches) distance, and with his head supported by a forehead-and-chin rest (Fig. 4). The screen was uniformly illuminated to a brightness of 10 millilamberts by eight gas-filled tungsten-filament lamps. This required an illumination of approximately 11.6 foot-candles. The lamps were enclosed in boxes, four of which, *LLLL*, are shown in Fig. 1.

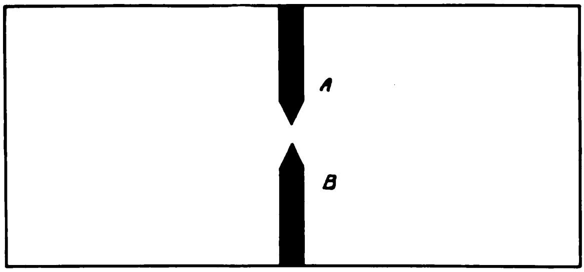
The extent of bright field to which the eye was subject was controlled by a series of diaphragms (*M–M*, Fig. 1) with various central openings, any one of which could be slid into a frame, and held in a vertical position opposite the subject and at a distance of 45 cm. (18 in.) from his eyes. The end of the room in which the subject sat was kept almost completely dark by curtains of black material, hung in the plane of the diaphragm *M–M* and completely filling the cross-section of the room, and in consequence the side of the diaphragm toward the subject reflected almost no light toward his eyes. In addition, the diaphragms and the frame supporting them were painted a dead black. The opening in the diaphragm thus presented a border of variable dimensions, within which a limited central portion of the illuminated white screen *S–S* could be seen in the midst of complete darkness.

The test-object was located at the center of this white screen, and consequently appeared within the area exposed by the diaphragm. Owing to the difference in the distances (45 cm. and 3 meters) it could not be made to appear centrally with both eyes at once. With the eyes fixed upon the test-object, there was sometimes an apparent doubling of the diaphragm-opening, which was especially noticeable with the smaller sizes, and a possible source of disturbance which will be discussed later.

The test-object (Fig. 2) consisted of an irregularly moving stylus, *A*, and the subject was required to keep a second stylus, *B*, in exact opposition to it by means of a hand-wheel

(*W*, Fig. 1) conveniently located on the table at his right hand. These appeared in a rectangular opening 152 mm. (6 in.) wide, and 70 mm. (2¾ in.) high, which was made in a sheet of thin metal forming the central part of the white

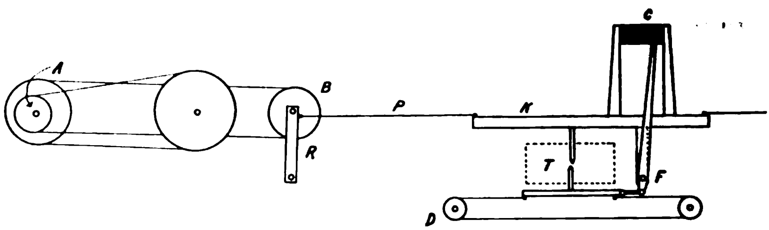
FIG. 2.



The Test-Field. The upper stylus *A* moved slowly and irregularly back and forth. The subject's task was to keep the lower stylus *B* in a position opposite to it.

screen. The moving (master) stylus was seen in silhouette, projecting downward from the upper border, and the following stylus projected upward from the lower border, both working close behind the margins of the opening. They were each 6.4 mm. (¼ in.) wide, tapered to a sharp point for an equal length, and the points cleared each other by 4.8 mm. (3/16 in.) in passing. Both of these were lacquered dead black.

FIG. 3.

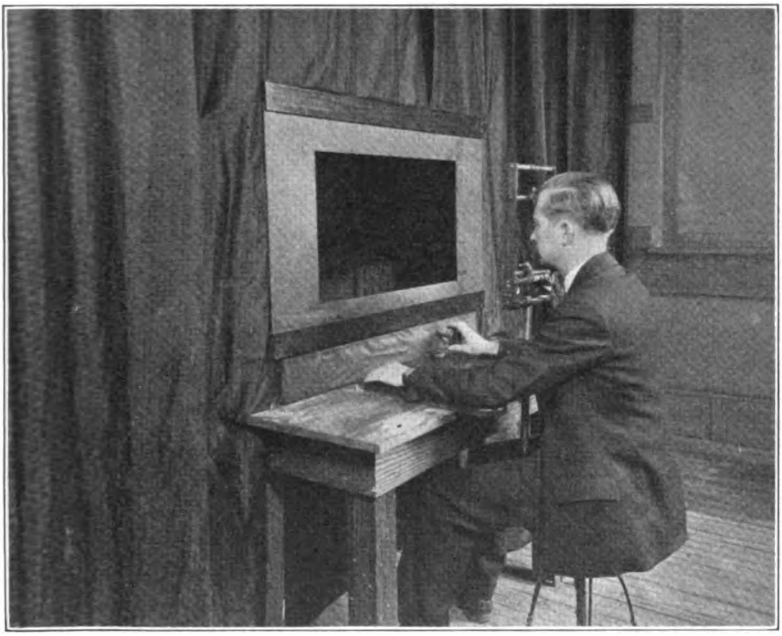


Detail of the Mechanism. The four eccentric pulleys at the left, when *A* was driven, gave the rocker *R* an irregular oscillatory motion, transmitted to the carriage *K*, bearing the upper stylus. The pulley *D* is fixed on the end of the rod *R*, Fig. 1, and actuates the lower stylus. The particular bar of the commutator *C*, upon which the contact rested, indicated the discrepancy between the two styluses, and by this means the appropriate counter was worked at intervals of 0.64 sec. whenever the master-contact was made.

The moving stylus was mounted on a sliding carriage (*K*, Fig. 3), and driven by a mechanism consisting of a piano-wire running over a set of four pulleys of different diameters, each one bored 3 mm. (⅛ in.) eccentrically.

One of these (*A*, Fig. 3) was fixed on its shaft and was driven slowly, the wire caused the others to rotate, and the eccentricity of the pulleys gave rise to the movement of one of their number *B*, which was mounted on a rocking arm, from which its movement was communicated, by another

FIG. 4.



A Subject in Working Position. The head-rest, the mask *M–M* and the hand-wheel *W* are shown. Compare with Fig. 1.

wire *P*, to the sliding carriage *K* and to the master-stylus. This wire was kept taut by means of a counter-weight, acting through a wire attached to the opposite end of the carriage *K*. The two other pulleys revolved freely on fixed axes. The effective diameters of the four, measured at the bottom of their respective grooves, were proportioned to each other approximately as 5, 7, 9 and 11. These numbers therefore represented the relative periods of four approximately harmonic movements each of 6.4 mm. (¼ in.) length between extremes, and the movement of the axis of pulley *B*

was the composite of these three. The possible extremes of movement of the center of the pulley *B*, which were seldom reached, were therefore 25 mm. (1 in.) apart. The diameters of the pulleys are represented by numbers which are prime to each other; wherefore even if the diameters were accurately proportioned, the identical movement could not be repeated

Fig. 5.

General View of Apparatus. Compare with Figs. 1 and 3. The reverse side of the screen *S–S* shows at the right. The battery of solenoids and the counters thereby operated are shown in the foreground.

for a very long time. Thus the drive pulley actually made one revolution in 25 seconds. Hence the other three completed one revolution in 35, 45 and 55 seconds respectively, and the time for the complete cycle, granting these proportions to be accurate, was the least common multiple of these four, 17,325 seconds or 4 hours, 48 minutes and 45 seconds. Need-

less to say, it was not possible to anticipate the movement, although this was never what could properly be called rapid.

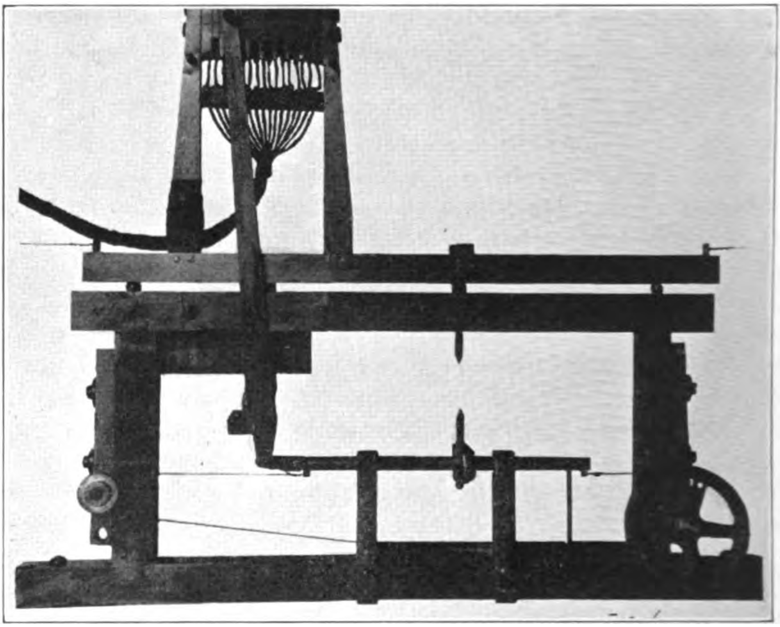
On the further wall of the room, 2.06 meters (6 ft. 9 in.) beyond the opening in the screen, a sheet of white cardboard (*G*, Fig. 1) was placed, ruled with india ink in lines about 0.53 mm. (.021 in.) wide, 4.8 mm. (3/16 in.) apart and inclined at 45°. This was so placed as apparently to fill the screen opening; it was illuminated by an independent lamp to equal brightness with the screen, and formed the background against which the two styluses were seen. It appeared from a few preliminaries that this sort of a ground made the apparatus more sensitive, but this has since appeared doubtful.

The degree of accuracy with which the subject was able to follow the moving stylus was measured by an automatic recording apparatus. The sliding carriage bore a set of 17 insulated copper bars which formed a commutator, over which a small rolling contact could pass (*C*, Fig. 3), attached to the upper end of a light lever. The fulcrum of the lever, *F*, is attached to the sliding carriage, and its lower, short arm is attached to a small slider which carries the following stylus. This is operated by the pulley *D*, Fig. 3, by means of the hand-wheel *W* and rod *R* shown in Fig. 1. The result is, that if the lower stylus follows the upper one *exactly*, the contact will remain stationary at the center of the commutator. Otherwise, the bar on which the contact rests is an index of the discrepancy. Each bar of the commutator was electrically connected to a solenoid operating a counter, and the discrepancy was recorded, every 0.64 second, by a master contact which permitted that one of the 17 counters to operate which was connected with the bar of the commutator upon which the rolling contact rested at that instant. Fig. 5 is a general view of the recording apparatus, showing the battery of solenoids with attached counters and the mechanism carrying the styluses, which is again shown in detail in Fig. 6.

The counter-readings, in connection with the displacement corresponding to each bar, therefore constituted a set of classified data, showing at once the distribution of the subject's inaccuracy in following the master-stylus. Such a distribution, taken over the experimental period of 5 minutes,

yielded two results,—the first, a mean displacement, showing the systematic tendency on the part of the subject to set the follower somewhat off its geometrically "opposite" position; the second, the index of scatter about that point of mean displacement. For the second of these, the standard devia-

Fig. 6.



The traveling carriage, following stylus and commutator shown in Figs. 3 and 5.

tion was used; that is, the square root of the mean squared deviation of the following stylus, measured from its mean position relative to the master-stylus.

The extent of the bright fields exposed by the various diaphragms could be expressed in various ways. The distance from the eyes of the subject to the diaphragm was uniformly 45.3 cm. (17.8 in.). In the following table are given the height and width of each diaphragm opening, the rectangular area of the same (in square feet) projected at a distance of 10 ft. upon a plane normal to the line of vision, as upon the screen S, and the angle subtended by the radius of a concentric

circle in the same plane equal in area to the rectangle. This last is, therefore, an approximate index of the angular distance to which the border of the dark surroundings has been removed from the line of direct vision in each case.

	Number.					
	1	2	3	4	5	6
Dimensions, mm. .	25 x 78	52 x 105	101 x 154	203 x 254	405 x 460	400 x 710
Proj. area, sq. ft...	.95	2.7	7.6	25.0	91.	138.
Angle............	3.2°	5.3°	8.9°	15.7°	28.2°	33.6°

The standard deviations are given in Table I, separately for each of the thirteen subjects. Each one is obtained from the pooled and classified data of 12 runs of five minutes each under the conditions indicated. The actual number of data recorded on the counters per five minutes was somewhat variable and in the main more than 400, each result stated in the body of the table representing the standard deviation computed from a mass of classified data ordinarily in excess of 5000 in number, and seldom less. Reference to the last column of the table will show that the uncertainty represented by the standard deviation was unequal for the different subjects, ranging from 0.475 minutes' visual angle to 1.067, a ratio of a little more than 2 : 1. The geometric mean for all subjects was 0.725 minutes. These figures are therefore of about the same order as the values stated for visual acuity, one minute or somewhat less. In the separate columns of the table, the mean values of the standard deviations are given for the various areas of bright field, arbitrarily numbered from 1 to 6. The second column under each of these is the percentage deviation of the separate mean from the mean for all six of the mask-openings, last column; and at the foot of the table are given (*a*) the averages of these percentage deviations from the mean of all, with due respect to sign, at each stage. The conclusion would be that a rather abrupt change takes place between stages 3 and 4 as the extent of the bright field is increased, in the sense of greater precision of following to the extent of 6 or 7 per cent. As subject No. 12 was somewhat erratic in stages 1 to 3, the second

TABLE I.

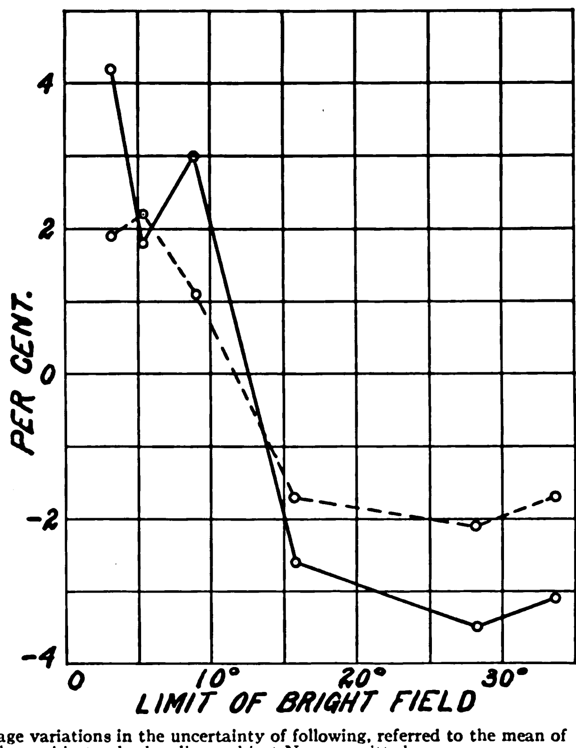
The Standard Deviation of Settings in Minutes' Visual Angle for the Six Conditions of the Experiment and for Each of the Thirteen Subjects Participating.

At the head of the table are given the various extents of the bright field, in the upper row in square feet at 10 feet distance, and in the lower in degrees angle subtended by the radius of an equal circle. The number following each decimal in the body of the table is its percentage deviation from the mean of the six for the same subject. At the foot: *a*, mean percentage deviation for all subjects, *b*, for all except No. 12. At the extreme lower right is given the geometric average of the thirteen averages in the column above.

Subject.	Extent of Bright Field.												Av.
	.95		2.7		7.6		25		91		138		
	3.2°		5.3°		8.9°		15.7°		28.2°		33.6°		
1	.983	− 1	1.032	+4	1.063	+ 7	.973	− 2	.970	− 2	.938	− 6	.993
2	.617	+ 6	.632	+8	.548	− 6	.524	−10	.614	+ 5	.570	− 2	.584
3	1.096	+ 3	1.098	+3	1.078	+ 1	1.020	− 4	1.046	− 2	1.062	0	1.067
4	.930	0	.988	+6	.914	− 2	.895	− 4	.890	− 4	.967	+ 4	.931
5	.891	+ 3	.874	+2	.893	+ 4	.830	− 4	.841	− 2	.837	− 3	.861
6	.472	− 1	.466	−2	.490	+ 3	.494	+ 4	.464	− 2	.463	− 3	.475
7	.527	+ 3	.518	+2	.515	+ 1	.499	− 2	.496	− 3	.506	− 1	.510
8	.928	+ 7	.887	+2	.850	− 2	.876	+ 1	.805	− 7	.852	− 2	.866
9	.642	− 7	.700	+1	.709	+ 3	.703	+ 2	.688	0	.696	+ 1	.690
10	.724	+11	.658	0	.622	− 5	.630	− 4	.638	− 3	.658	0	.655
11	.653	0	.640	−2	.660	+ 2	.674	+ 4	.618	− 5	.652	0	.650
12	.868	+32	.627	−4	.828	+26	.563	−14	.528	−20	.525	−20	.656
13	.747	− 1	.782	+3	.806	+ 7	.750	− 1	.753	0	.697	− 8	.756
a		+4.2		+1.8		+3.0		−2.6		−3.5		−3.1	.725
b		+1.9		+2.2		+1.1		−1.7		−2.1		−1.7	

line, *b*, at the foot of the table gives the mean values for the other twelve subjects, excluding his. The results still lead to a similar conclusion, except that the change is of less extent, amounting to about 4 per cent. These results are plotted in Fig. 7, from which it will be noted that the exclusion of subject No. 12 yields a smoother curve.

FIG. 7.

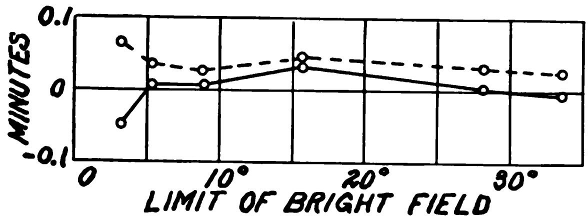


Percentage variations in the uncertainty of following, referred to the mean of all values as 0. Solid line, all 13 subjects; broken line, subject No. 12 omitted.

A word is still to be said about the systematic deviation (or deviation of the average setting), of the various subjects from the point of geometric opposition, as contrasted with the "scatter" represented by the standard deviation which has just been discussed. This also is various for the different subjects; averaging as much as 0.47 minute to the left in one extreme case, and 0.20 minute to the right in the opposite extreme. Comparison of the results for the variously sized

fields (see Fig. 8, solid line) would indicate a tendency for the individual to set slightly to the left of his average position when the smallest opening is used, to the extent, in the

FIG. 8.



Deviation of mean position, with reference to geometric opposition, in minutes' visual angle. Solid line, all subjects; broken line, No. 12 omitted.

average for the 13 subjects, of about 0.046 minute, which value is 3.54 times its probable error ($\pm$ 0.013). This ratio would indicate a probability of about 60 : 1 that the difference 0.046 is not due to pure chance. However, the difference seems almost small enough to be insignificant, since it is less than one-twentieth of the value ordinarily stated as "normal" visual acuity. The principal effect of increasing the area of the bright field is the reduction in the degree of scatter of the setting, rather than a systematic tendency to set away from geometric opposition in one direction or the other.

There is some question as to the practical application of this result. The effect of decreasing the uncertainty of a visually controlled operation to the extent of 4 to 7 per cent. will depend much, in any particular case, upon the ratio primarily existing between the uncertainty of the sense-organ on the one hand, and on the other, the fixed requirement imposed upon it by the character of the work. In Case I, let us say, this ratio is such that the failures to see outnumber the successes by a large majority. In this case, decreasing the uncertainty of vision will be equivalent to increasing the "tolerance" in the requirement in just about the same ratio. The successes, for instance, initially 10 per cent., will be increased about to 10.7 per cent. by a 7 per cent. enhancement of the certainty of the eye brought about, let us say, by improvement in the lighting. In Case II, however, in which

the successes are initially only slightly below 100 per cent., say 98, no such rule will apply. The probability tables indicate that in this instance the same shrinkage in the uncertainty of vision will increase the successes no more than to 98.72 per cent.—an increase of 0.7 instead of 7 per cent. However, if we are interested in the decrease in the failures, we find that these have shrunk from 2 to 1.3 per cent.; that is, they have decreased by 35 per cent. of their initial number. The fact should never be overlooked that in the industries the economic significance of such an improvement will depend entirely upon the values that are to be attached to successes and failures respectively, which, in turn, depend upon many things not included within the psycho-physiology of the worker.

There is a further unfavorable factor undoubtedly present in the practical situation which does not appear in its present experimental counterpart. That is the effect of the glance of the worker into the dark surroundings of his working field from time to time, either as he relaxes for an instant from his work, or as he necessarily peers into the darkness for some definite purpose. In the latter case, as we know, there is an enforced delay, while his eyes adapt themselves to the dim conditions,[2] and in either case, upon their return to the work, an effect is, in all probability, present such as that shown by the experiment, but temporarily, at least, to a heightened degree. With respect to this consideration then, the experimental differences do not reflect all of the effect practically present.

In considering possible applications of the results here given, it is important to remember that in the experiment the edges of the diaphragm limiting the extent of the bright field are within arm's length, while the test-object is at several times this distance from the subject's eyes. It has already been remarked that this made it impossible for both eyes at once to see the test-object central within this area, and that, as a matter of fact, the smaller openings were seen double when the eyes were fixed upon the test-object. This situation is not of the sort encountered in practical situations.

[2] Cobb and Moss, "Lighting and Contrast," *Trans. I. E. S.*, XXII, 1927, pp. 198–202.

A well-illuminated sheet of print, for example, presents a condition in which the borders of the bright area are in the plane for which the eyes are accommodated and converged. It is perhaps to be expected that this latter situation, being of the kind to which the eyes are accustomed by life-long usage, would be less disturbing than the laboratory situation of the present experimental work. It should follow from this, that in the practical situation the differences would be smaller than the experiments have shown, or that the eyes would without greater disturbance tolerate a closer approach of the dark surroundings to the line of direct vision than these results would indicate.

SUMMARY.

1. The purpose of the present paper is to estimate the extent of bright surroundings necessary to abolish the known, adverse effect of dark surroundings upon vision on a small, bright, working field.

2. The test of vision used was the accuracy with which the subject could keep a manually operated stylus in opposition with another, slowly and irregularly moving, mechanically operated stylus. Both of these were seen in silhouette upon a small, bright field.

3. The results here stated are derived from a total of 390,000 measurements.

4. The precision with which the subjects could follow the moving stylus in general was highest with the largest extent of bright surroundings, lowest with the smallest. Although represented by some 65,000 measurements for each of the six sizes of surrounding field used, the results were still somewhat irregular.

5. The extreme difference in precision was from 4.3 to 7.7 per cent. A large part of this difference, 2.8 to 5.6 per cent., occurred when the border of the bright surroundings was pushed outward from 8° to as far as 16° from the visual line. The plotted results would indicate that there is no advantage to be gained by extending the bright surroundings beyond this.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THIRTEENTH ANNUAL MEETING OF THE OPTICAL SOCIETY OF AMERICA.

The thirteenth annual meeting of the Optical Society of America was held at the Bureau of Standards on November 1 to 3, inclusive. The meeting was opened by the Secretary of Commerce, who delivered a short address of welcome.

An extensive exhibit of optical instruments, appliances, books, and photographs was arranged by the bureau in connection with the meeting. The latest commercial instruments produced here and abroad were shown by representative manufacturers, while instruments in regular use were on view in the laboratories. A special feature of the exhibit was a series of microscopes illustrating the development of this important instrument from 1665 to the present day. This collection was loaned by the Medical Museum of the United States Army. A collection of photographs and books, illustrating the development of optics, was made available through the courtesy of the Smithsonian Division of the Library of Congress.

This meeting of the Optical Society was designated by the executive council as "The Michelson Meeting" in honor of Prof. Albert A. Michelson, whose first communication on a method for measuring the velocity of light was published just fifty years ago. Professor Michelson on November 2 announced the results of his repetition of the Michelson-Morley experiment on ether drift, his latest work confirming the famous experiment of 1887 in showing the absence of any measurable variation in the velocity of light in different directions.

One of the most interesting features of the meeting was the showing of the remarkable motion picture film depicting the rotation of the planet Jupiter. This film was made by Prof. W. H. Wright at the Lick Observatory in coöperation with the Eastman Research Laboratories.

On the evening of November 2 a dinner was held in honor of Professor Michelson. At this dinner Dr. Herbert E. Ives

* Communicated by the Director.

presented to the society the Frederic Ives medal, which Doctor Ives has endowed in honor of his father, and which is to be awarded by the Optical Society of America each year for distinguished work in optics.

Papers by members of the bureau's staff were as follows:

A telescope objective especially free from spherical aberration, by I. C. Gardner;

An optical depth gauge, by I. C. Gardner;

An interference method for the determination of central and oblique aberrations, by A. H. Bennett;

Apparatus for the measurement of the reflective and transmissive properties of diffusing media, by H. J. McNicholas;

Apparatus for accurate and rapid measurement of spectral transmission and reflection, by K. S. Gibson;

The history and present status of the physicist's idea of light, by Paul R. Heyl;

The wave-lengths of the *D* lines of sodium in absorption and emission, by C. C. Kiess;

Recombination of atomic ions and electrons, by F. L. Mohler and C. Boeckner;

Light scattering in liquids, by R. M. Langer;

The absorptive properties of carotin and xanthophyll in the visible and ultraviolet, by H. J. McNicholas;

Least retinal illumination by spectral light required to evoke the "blue arcs of the retina," by Deane B. Judd.

NEON VISIBILITY TESTS.

DURING August and September, a visibility test on the light from a neon lamp as compared with the light from an incandescent filament lamp with red color filter was conducted at Moody Point, Maine. The apparatus for the test was erected at a place on the coast, where a range for observation of about 4.5 miles was available, the particular location having been selected on the basis of fog records of the Bureau of Lighthouses for some years. The apparatus was in no sense an aviation beacon, but was designated solely for observation by observers patroling the shore.

The rotating experimental beacon was so operated that 3 flashes of light could be seen successively—a neon flash, a red

flash from an incandescent lamp with color screen to match the neon color, and a clear flash from an incandescent lamp without color screen. The apparatus used to produce the flashes consisted of three lens units, each with its corresponding light source (lamp). These lens units were plano-convex lenses, of 140 millimeters focal length, 110 millimeters aperture, the actual light source in each case being a hole 15 mm. in diameter in a metal plate fixed in the focal plane of the lens, each illuminated by its individual lamp.

For the neon lamp and the incandescent lamp with red color filter, the 15 mm. aperture in each unit had the same candlepower, the same color, and the same horizontal light distribution as closely as was experimentally possible. When the red color filter was removed from its unit the two incandescent beams were also of approximately the same candlepower, color, and horizontal distribution. Three different neon lamps of the hot cathode type were used. The complete equipment, with motor, rheostats, and electrical measuring instruments, was erected in a small shed.

Thirty-three sets of observations were made; in clear weather, in haze, in fog, and in rain. One fog observation was made in daytime. The method of observation varied somewhat, depending on the weather, but generally observations were made from 5 stations, approximately 4.5, 3.5, 3, 2.5 and 1.25 miles from the beacon. The observer walked away from the beacon to the end of the range and back, or from the end of the range towards the beacon. Two persons were engaged on the work,—one observed while the other attended the apparatus, and alternately.

Observations were made with the naked eye and with a photometric wedge. No differences, sufficiently great to be detected by the methods used in this test, were found between the visibility of light from a neon lamp and light of the same color, candlepower, and horizontal distribution produced by an incandescent filament lamp with color screen.

With regard to the comparison of the clear incandescent lamp and incandescent lamp with red color screen, the red filter does not increase the range under any weather conditions, but there is some evidence that the red filter does not reduce the range as much in foggy weather as it does in clear weather.

A SYSTEM FOR FREQUENCY MEASUREMENT BASED ON A SINGLE FREQUENCY.

AN accurate method of rapidly checking the frequencies of piezo oscillators used as the frequency standards for stations has been developed at the bureau and is in daily use. The method is suitable for calibration of either piezo oscillators or frequency meters in terms of a standard temperature-controlled piezo oscillator. The accuracy obtained is dependent only upon the accuracy of the standard piezo oscillator.

The apparatus required consists of a temperature-controlled piezo oscillator the frequency of which is a multiple of 10 kc., a 10 kc. radio-frequency generator, an auxiliary generator covering the range of frequencies desired, a special beat indicator, an audio-frequency generator, and a frequency meter.

The radio-frequency generator is adjusted and maintained at 10 kc. in terms of the standard piezo oscillator. The correct adjustment is shown by a special form of beat indicator which gives both visible and audible indication when the radio-frequency generator is so adjusted that a harmonic of its frequency is exactly the same as the frequency of the standard piezo oscillator. A second auxiliary radio-frequency generator is then set approximately by means of a frequency meter to the assigned frequency of the broadcasting station whose piezo oscillator is to be tested and then adjusted to the exact frequency, which is a harmonic of the ten-kilocycle generator, by the special beat indicator.

After these adjustments are made an audible note will in general be heard when listening in the telephone receivers of the piezo oscillator under test. This note represents the difference in frequency between the piezo oscillator and that of the auxiliary generator. The beat note heard in the telephone receivers of the piezo oscillator is then matched with a similar note from a calibrated audio-frequency generator. This audio-frequency value is then added to or subtracted from the frequency as given by the harmonic of the 10 kc. generator.

The method has the advantages of great accuracy, high precision, adaptability to almost any frequency measurement, and ease of operation.

A paper which has been prepared describing this method will be published shortly.

RADIO-FREQUENCY TRANSFORMER THEORY.

RADIO-FREQUENCY transformer theory has for some time been reduced to mathematical treatment. The accepted equations are simple and usually quite effective but in many cases, computations based on these equations are not in entire agreement with careful laboratory measurements. This lack of agreement was considered in a paper, "Note on Radio-frequency Transformer Theory," by Harry Diamond and E. Z. Stowell, Proceedings, Institute of Radio Engineers, September, 1928. It was found to be due chiefly to the existence of a capacitance coupling between the primary and secondary windings which modifies the transformer performance, but the effect of which is usually considered negligible. When this factor is not neglected, the resultant equations which are developed in this paper yield a closer agreement with experimental data. Copies of this paper are not available from the Government.

THERMAL EXPANSION OF MULLITE FROM 20 TO 1800° C.

A BRIEF description of an apparatus for making thermal expansion observations of refractories from 20 to 1800° C. appeared in Technical News Bulletin No. 134 (June, 1928).

A study of the expansion behavior of mullite, prepared from raw materials obtained from various sources, was recently completed with this apparatus. These materials are as follows:

Sample *A* prepared from andalusite.
Sample *B* prepared from dumortierite.
Sample *C* prepared from Indian cyanite.
Sample *D* prepared by electrically fusing the necessary proportions of alumina and silica to produce mullite.

Specimens measuring approximately 1 by 1 by 6 inches were used for expansivity measurements. A comparison of the expansion characteristics of the several specimens of mullite is given in the following table.

Sample.	Average Coefficient of Linear Thermal Expansion from 20 to 1000° C.		Total Expansion at 1000° C. in Percentage of Unit Length.		Contraction Commences at		Average Coefficient of Linear Thermal Expansion from 20 to 1400° C.		Temperature at Which Maximum Expansion is Reached.		Maximum Total Expansion in Percentage of Unit Length.	
	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.
	$\times 10^{-6}$	$\times 10^{-6}$			°C.	°C.	$\times 10^{-6}$	$\times 10^{-6}$	°C.	°C.		
A....	5.8	5.2	0.51	0.46	None	1770	6.5	5.7	1795	1770	1.390	0.995
B....	5.6	5.6	.495	.495	1400	1520	5.0	5.2	1400	1520	.685	.745
C....	5.4	5.6	.476	.490	1370	1700	[1]4.9	5.5	1370	1700	.603	.842
D....	5.0	5.3	.494	.520	1425	1600	5.4	5.3	1430	1600	.767	.840

[1] Coefficient refers to temperature range, 20 to 1260° C.

All specimens had been fired to at least 1400° C. previous to testing. The maximum temperature reached in the furnace while testing the various materials was as follows:

Maximum Temperatures in Degrees C.

	First Run.	Second Run.
A....................................	1795	1800
B....................................	1670	1730
C....................................	1795	1800
D....................................	1765	1765

Sample "*A*" did not contract, during the initial heating, up to the maximum temperature (1795° C.) used. As shown in the table, it was the only specimen that did not contract during heating. The rate of expansion increases decidedly at about 1500° C. Petrographic examination indicates this material to be composed largely of well developed crystals of mullite and some corundum.

Sample "*B*" has a nearly uniform rate of expansion from 20 to 1500° C. with the exception of an interval between 600 to 700° C. where the rate increases appreciably. Petrographic examination of sample "*B*" indicated a large percentage of glass intermingled with mullite. It contains no corundum.

In spite of sample "*C*" having been heated at 1400° C. for ten hours, shrinkage during the first run commenced at 1250° C. Petrographic examination shows that the second heating caused a considerable growth in the size of the crystals.

Petrographic examination of sample "*D*," after the first heating, shows the material to be composed almost entirely of mullite. Only a small percentage of corundum and glass is present, which is in contrast to samples "*A*" and "*C*."

The rate of thermal expansion of these various specimens of mullite is approximately the same from room temperature to 1000° C. Considerable differences occur in their expansion behavior at the higher temperatures.

Cod Liver Oil. CHARLES E. BILLS (*Chem. Rev.*, 1927, *3*, 425–442) has made an elaborate review of the chemical literature on cod liver oil, citing 90 papers in his bibliography. This oil was originally obtained by natural disintegration or "rotting" of the livers. This process was displaced, first by the steam kettle, then by direct steam rendering. The "stearine" is removed from the crude product by chilling and filtration. The occurrence of 17 fatty acids in cod liver oil has been reported; the presence of 9 of these acids is reasonably well established, the presence of the remaining 8 acids less well established. All the known acids fall into a broad series $C_nH_{2n-2x}O_2$ where n has a value between 14 and 22 and x is the number of double bonds which may range from 0 to 6. Morrhuic acid or sodium morrhuate, which has been used in the chemotherapy of tuberculosis and leprosy, is really a cod liver oil soap prepared for intravenous administration. The oxidation and consequent rancidity of cod liver oil is an autocatalytic process accelerated by the formation of organic peroxides and retarded by foreign substrates; they are most readily avoided by expeditious rendering. Cod liver oil may be hydrogenated; this process destroys both the vitamins and the fishy smell. Inorganic constituents may be present in the oil, such as iodine (0.0001 to 0.0005 per cent.), bromine, chloiine, nitrogen, phosphorus, organic sulphur, zinc, and the alkalies. The unsaponifiable fraction contains cholesterol, other complex alcohols, a hydrocarbon (squalene or spinacene), a lipochrome or pigment, and vitamins (fat-soluble A and fat-soluble D).

J. S. H.

Mode of Action of Vitamin D. The fat-soluble D vitamin or antirachitic vitamin is an important factor in the prevention of rickets. LESLIE J. HARRIS of Cambridge University (*Science Progress*, 1928, *23*, 68–74) discusses the theory that this vitamin governs the acidity (hydrogen ion concentration) of the intestinal contents, and thus controls calcium metabolism. The vitamin causes an increased acidity in the intestine. As a result, ingested calcium phosphate becomes more soluble, is absorbed in greater amount into the blood stream, and is deposited in greater amount in the bones. Lack of the vitamin and resulting decreased acidity (increased alkalinity) of the intestinal contents converts the calcium salts into insoluble compounds, and prevents their absorption, and use in bone formation.

J. S. H.

NOTES FROM LIGHTING RESEARCH LABORATORY, NATIONAL LAMP WORKS OF GENERAL ELECTRIC COMPANY.*

PROPORTION OF ENERGY RADIATED BY INCANDESCENT SOLIDS IN VARIOUS SPECTRAL REGIONS.[1]

By L. L. Holladay, Physicist.

THIS paper presents a speedy and accurate method of computing the portion of the total energy radiated by an incandescent solid in a given spectral region. The theory of the method is developed and specific data are presented on tungsten and several other types of incandescent radiators.

By combining Planck's equation for the spectral distribution of energy from a black-body radiator with Wien's displacement law connecting temperature T with the wavelength λ_m at which the maximum energy occurs, the proportion ϕ of spectral energy emitted from a black-body radiator at temperature T in the spectral region between wave-lengths zero and λ has been carefully computed. From a table and plot of these results, the proportion of energy in any region of the spectrum of a black-body at any temperature may be quickly determined.

It is further shown that if any incandescent solid of temperature T has the same distribution of energy in a given spectral region as a black-body radiator at temperature T_c (the color temperature of the incandescent solid), the proportion of radiant energy in this region of the spectrum of the incandescent solid at temperature T is G times as great as that from the black-body radiator at temperature T_c. If the total emissivity of the incandescent solid is ϵ_t at temperature T and if its color emissivity in the spectral region under consideration is ϵ_c (i.e., if ϵ_c is the ratio of energy radiated in the given spectral region by the incandescent solid at temperature

* Communicated by the Director.

[1] *Jr. O. S. A. and R. S. I.*, Vol. 17, November, 1928, p. 329.

T to the energy radiated in the same spectral region by a black-body radiator at temperature T_c) then the value of

$$G = \left(\frac{\epsilon_c}{\epsilon_t}\right)\left(\frac{T_c}{T}\right)^4.$$

Also, if l_1 is the luminous efficiency of the incandescent solid, and if l is the luminous efficiency of a black-body radiator at temperature T_c, the value of

$$\frac{G = l_1}{l}.$$

Several values of G are given for carbon, osmium, tantalum and tungsten radiators. Values of G for regions in the visible spectrum of incandescent tungsten are about 2.1 at a temperature of 1500° K., 1.52 at 2000°, 1.27 at 2500°, 1.16 at 3000° and 1.10 at 3500°. These values of G for tungsten are nominally correct only for regions in the visible spectrum, but are probably approximately correct for use in the ultra-violet regions as well.

VISION IN FIELDS BRIGHTER THAN THEIR SURROUNDINGS.

By P. W. Cobb and F. K. Moss.

PREVIOUS work has shown that vision is at its best when the visual object is seen in surroundings equal in brightness to its own; however, no investigation has been made of the limiting size of the surrounding field which is effective in this respect. In lighting practice it may be economically undesirable to maintain a uniformly high intensity of illumination over large areas, where a very high level of illumination is required on certain work. The purpose of the research abstracted here was to determine the limits within which an adverse effect on vision could be expected from the outlying area illuminated to a lesser intensity.

The visual test used was the precision with which a manually operated pointer could be kept in opposition to a similar pointer above it which moved slowly and irregularly from side to side. The two vertical pointers were separated

by a small vertical distance and as seen by the subject appeared in silhouette against a large white surface illuminated to a brightness of 10 millilamberts. The extent of the deviation from exact opposition was automatically recorded. The subject was seated in a darkened space, and viewed the pointers through an opening in one of a set of dark screens which exposed the white screen about the pointers to any desired area. The latter was varied in extent and the effect on vision was determined in each case. The table summarizes 400,000 settings of the manually operated pointer.

Extent of Illuminated Area Surrounding Pointers. Angle Subtended by Circular Area.	Extent of Illuminated Area Surrounding Pointers. Corresponding Area in Sq. Ft. at Ten Feet.	Per Cent. Deviation from Mean Error in Setting Pointer.
6 Degrees	1	+ 4.2
11 Degrees	3	+ 1.8
18 Degrees	8	+ 3.0
31 Degrees	25	− 2.6
56 Degrees	90	− 3.5
77 Degrees	140	− 3.1

These data indicate that most of the disadvantage of dark surroundings, or outlying area, occurs when the bright central area is less than 25 sq. ft. at a distance of ten feet. This is equivalent to a circle 5.6 ft. in dameter at ten feet or 1.1 feet in diameter at two feet and subtending an angle of about 30 degrees. Between the smallest and largest fields used, there is a difference of about 7 per cent. in the precision of seeing. Whether such differences are significant in practice depends upon the requirements of the work. These data were taken at but one level of brightness, 10 millilamberts, corresponding to 11.6 foot-candles on a white surface of 80 per cent. reflection-factor. In practice with the low reflection-factors often found in work-places, 10 millilamberts may represent as much as 100 foot-candles or more. Therefore, the present data lie within the range of intensities of illumination used in lighting, and are conservative since the most distracting condition was used—that of a bright area sharply defined in dark surroundings. These data do not take into account possible physiological factors, such as eye-fatigue which cannot at present be measured quantitatively. How-

ever, our experience in this investigation leads us to believe that with good general lighting the spot of localized high-intensity illumination could be many times as bright as the surroundings without noticeable eye-discomfort provided the angular extent of the spot receiving localized lighting is about 30 degrees in diameter.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

OPTICAL SENSITIZING OF SILVER HALIDE EMULSIONS. I ADSORPTION OF ORTHOCHROME T TO SILVER BROMIDE.[1]

By S. E. Sheppard and H. Crouch.

THE absorption spectra in the visible and ultra-violet of Orthochrome T bromide have been measured in solvents and in water at various pH values. The adsorption of the dye to silver bromide was measured by mixing the two in various concentrations and then separating the phases. The grain-size frequency of the silver bromide was known so the calculation of the ratio of moles of dye per sq. cm. of surface of the grains could be calculated. Langmuir's adsorption equation was the only one found to fit the experimental determinations. As to the sensitizing of the silver bromide it is suggested that the dye is held to the bromide ion and that the photodecomposition is of an explosive character; thus one dye molecule could sensitize many silver bromide molecules.

NOTES ON MAKING DUPLICATE NEGATIVES.[2]

By C. E. Ives and E. Huse.

AFTER several years of experience, additional suggestions concerning the use of duplicating film have been made. The master positive should be as nearly as possible perfect in printing quality. A minimum density of 0.5 is necessary although overexposure should be avoided. The contrast of the master positive should be adjusted by the use of violet

* Communicated by the Director.

[1] Communication No. 337 from the Kodak Research Laboratories and published in *J. Phys. Chem.* **32**: *751. 1928; Phot. J.* **68**: *273. 1928.*

[2] Communication No. 356 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* **12**: *No. 34, 382. 1928; Amer. Phot.* **22**: *532. 1928.*

filters if necessary. Development should be complete but not excessive and should reproduce the contrast of the original exactly when printing is done through one violet filter (Wratten No. 39). Machine development is preferable to any other because it gives the uniformity that is required in duplication work.

The same quality considerations apply in making the duplicate negative. Contrast adjustments should not be made in the negative if they can be made in the master positive. When a duplicate negative of uniform printing density is required it is preferable to print it from a perfectly uniform master positive but if it becomes necessary to alter exposure in printing the duplicate negative, trial exposures should be made and tested by making final positives.

The printer for duplication work should give perfect uniformity of exposure and will give sufficient exposure if a 25-volt, 100-watt, concentrated filament lamp is used with an efficient relay condenser system or if a 300- or 400-watt lamp is used without condensers when printing speed is about 15 feet a minute.

LABORATORY HUMIDITY CABINET.[3]

By I. C. Matthews and A. M. Burgess.

An air-conditioning cabinet, designed to give temperatures and humidities approaching tropical conditions, for use in conducting a tropical weathering test on metals, photographic and other materials, is described. As improvements over existing apparatus of this nature, several features of construction are mentioned. These include (1) a box properly constructed of alberene stone which is corrosion resistant and a fair non-conductor of heat; (2) all parts which are exposed to moisture are made of copper or brass; (3) a thermostatically controlled steam coil is used as the heating unit; (4) the diaphragm valves are automatically operated by a recording and controlling instrument; and (5), all hangers and supports for holding articles to be tested are made of glass. Two photographs and a detailed drawing are included.

[3] Communication No. 345 from the Kodak Research Laboratories and published in *Ind. Eng. Chem.* **20**: *1239. 1928.*

THE FORMATION OF THE PHOTOGRAPHIC LATENT IMAGE.[4]

By S. E. Sheppard.

AN introductory portion reviews latent image and sensitivity theories. It is pointed out that the balance of evidence leads to the conclusion that the latent image consists of development centers composed chiefly of colloidal silver. These centers are formed by photochemical reduction at pre-existing sensitivity nuclei. These nuclei sensitize for light but not for X-rays, and are furnished by gelatin. They probably consist of silver sulfide, or silver, or both substances, in specks too small to induce developability.

The crystalline character of the silver halide grain implies a certain lattice energy. It is shown that this enters into the initial energy required to shift an electron. This initial energy quantum is much greater than that of photographically active light. Consequently, if the primary photochemical change is

$$\overset{-}{Br} + h\nu = Br + \theta$$
$$\overset{+}{Ag} + \theta \rightarrow Ag \text{ (Met)}$$

then the silver bromide first reduced cannot be under normal lattice constraints.

Investigations (with Dr. Vanselow) of the photo-potentials of silver: silver bromide electrodes in potassium bromide solutions demonstrate that electrons and bromine are released together by light acting on silver bromide. The potential change consists of an initial inertialess negativization passing over into a positivization. The positive potential rise can be reduced or eliminated by bromine acceptors, or replaced by bromine diffusion. It is concluded that the inner photoelectric effect occurs at sensitizing interfaces where the silver halide is disoriented. The formation of the latent image may be interpreted as a concentration effect, caused by orientation of sensitizing specks and silver halide at the

[4] The Sixth Hurter and Driffield Memorial Lecture, Communication No. 359 from the Kodak Research Laboratories and published in the *Phot. J.*, **68**: *397. 1928.*

interfaces. It is shown that the orientation hypothesis is adequate to explain the transition between general and optical sensitizing by silver sulfide, silver, or similar nuclei. As the number of nuclei per grain increases, and their size diminishes, the general sensitizing (concentration effect) decreases, the optical sensitizing (wave-length shift) increases. The special features of reciprocity failure and incomplete summation are also accounted for. Thus the existence of threshold intensities is deducible from deficiency of nucleus concentration for poorly sensitized grains. The existence of an optimum intensity is also explained by dispersity considerations. As the light intensity is increased, i.e., the quantum density, so is the chance of formation of new, independent nuclei competing with pre-existent ones in latent image concentration. At very high intensities, therefore, the grain acts more as with X-rays, where pre-existent nuclei are ineffective.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting Held Wednesday, November 21, 1928.*)

THE Stated Meeting of the Institute was called to order at eight-fifteen p.m. by the Acting President, Mr. Henry Howson.

The Secretary reported that the minutes of the October meeting had been printed in full in the Journal of the Institute for November, and moved that they be approved as printed. The motion was seconded and unanimously adopted and the minutes were declared approved.

The Secretary presented the following report concerning membership changes since the last report: Eight new Resident members, three new Non-Resident members, one new Student member; one death.

There being no further business, the Chairman introduced as the speaker of the evening Captain Hiram B. Ely, Ordnance Department, United States Army who spoke on the subject of "Aircraft Detectors and the Anti-Aircraft Problem."

The meeting adjourned at nine-forty p.m., with a rising vote of thanks to Captain Ely for his interesting and instructive paper.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, November 7, 1928.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, November 7 1928.

DOCTOR GEORGE S. CRAMPTON *in the Chair.*

The following report was presented for final action.

No. 2883: Monroe Calculating Machine.

The growth in the use of different forms of calculating machines has brought many of them before the Committee on Science and the Arts for investigation. One of the first of these was a calculating machine invented by F. S. Baldwin in 1874 for which he was awarded the John Scott Medal.

Since that time six machines of other inventors have been awarded the Scott Medal for either calculating or adding machines.

The present form of the Monroe machine includes the many improvements, that have been made on the Baldwin Machine in the past fifty years until the arithmetical operation of addition, subtraction, multiplication, division and their various modifications are carried on with surprising quickness and accuracy.

One notable improvement is that of adding a series of numbered keys by the use of which multiplication can be carried on automatically.

In order to multiply a number by 37, for example, this number is first set on the keyboard and on depressing the plus key it appears in the lower of two horizontal dials while in an upper dial the figure 1 appears showing that the num-

ber has been taken once. On depressing the multiplying key numbered 6 the given number is added continuously six times and the number 7 appears on the upper dial, the product of 7 times the number appears in the lower dial. The carriage of the machine also moves from the units place to the tens and on depressing multiplying key 3 the number is multiplied by 3 tens or 30 making the entire multiplier 37, that number showing on the upper and the product showing on the lower dial. Automatic division can also be carried on. The machine in its most recent form is driven by an electric motor and is a most satisfactory aid in calculation.

The following reports were presented for first reading:

No. 2895: Masonite and Presdwood.

No. 2896: Gyro-Pilot.

No. 2897: Work of Mr. William H. Gartley in the Gas Industry.

GEO. A. HOADLEY,
Secretary to Committee.

THE JAMES MAPES DODGE FOUNDATION CHRISTMAS WEEK LECTURES FOR YOUNG PEOPLE.

THE Institute announces that we have invited Professor A. S. Eve, Director of the Department of Physics, McGill University, to be our Christmas Week lecturer for the present year. Dr. Eve will deliver three lectures on "Things that Spin; Things that Swing; Things that Wave," on December twenty-sixth, twenty-seventh and twenty-eighth, at three P.M., in the Hall of the Institute. The members of the Institute are reminded of these lectures and are requested to call them particularly to the attention of the young members of their families, and to other young people of school age. A ticket to the series should be regarded as a fitting Christmas present by any young person of intellect. Tickets can be procured through the Controller's Office. Price for the series: two dollars.

HOWARD MCCLENAHAN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, November 9, 1927.*)

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STUDENT.

MR. WALTON FORSTALL, JR., Student, Lehigh University, Psi Upsilon House, Bethlehem, Pa.

CONTRIBUTING.

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NECROLOGY.

Mr. J. E. Lonergan, Philadelphia, Pa.

LIBRARY NOTES.

RECENT ADDITIONS.

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BOOK REVIEWS.

Théorie Ionique de L'Excitation des Tissus Vivants. Par le Professeur Docteur P. Lasareff, Membre de l'Académie des Sciences de Leningrad, Directeur de l'Institut de physique et de biophysique de Moscou. x–240, pages, 25 x 16 cm., paper. Librairie Scientifique Albert Blanchard, Paris, 1928. Price, 40 francs.

Every manifestation of a physical phenomenon, however elaborate and precise the method employed in its observation, must finally be translated with some physiological action. The senses which are the final indicators are generally applied without much thought of the functioning of the mechanism through which stimulating effects are perceived, and a closer study of the subject is of more than passing interest in physical science. The work is in that field of biophysics in which a searching analysis is made by purely physico-chemical methods, of the capital rôle of ions in the phenomena of excitation of nerves and of muscles. With its many graphs and mathematical deductions the work resembles more a treatise on mathematical physics than one on a biological subject.

After developing the theory of excitation and establishing quantitative laws of the phenomena of the excitation of living tissue, those principles are applied to a consideration of the theories of vision, audition, touch and olfaction. Of particular interest to the physicist are the treatment of the theory of vision, color-sensation, persistence of vision, and other topics of a physiological nature which have already claimed his attention. The work is a model of logical analysis and thoroughness. It is thoroughly documented and contains many quotations in the language of their source (mostly German). Including the results of researches in the author's laboratory as late as 1927, the text is as fully up-to-date as can be reasonably be expected. A previous edition appeared in German in 1923. Those who would analyze the mechanism and its action of physical stimulus and resulting perception will not regret the effort for a perusal of this book.

L. E. P.

A Survey of Nitrocellulose Lacquer. By Bruce K. Brown (Formerly with Commercial Solvents Corporation) and Francis M. Crawford (Director of Patent and Research Information Departments, Commercial Solvents Corporation). 308 pages, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $7.50.

With the exception of a few pages of explanatory matter and some historical outlines this work consists of the list of patents taken out in the principal countries, and also a long bibliography and an index of materials named in the patents. It represents an enormous amount of labor and shows vividly the great industrial importance that these products have acquired. Their use has been enormously increased in connection with the automobile industry but the manufacture of nitrocellulose lacquer was well advanced many years ago. The development of aviation also stimulates greatly the manufacture of such materials. The comparison of the use of the materials for automobile lacquering is shown by the fact that in 1923 less than one per cent. of the automobiles made in the United

States were so treated, but in 1927 nearly one hundred per cent. were lacquered. This extensive adoption of this procedure followed the results of laboratory tests which showed the durability of the material. In the introductory text much information is furnished as to the nature of these products, and the principles on which they are produced and applied as well as a comprehensive account of the several types.

HENRY LEFFMANN.

INDUSTRIAL CHEMISTRY—AN INTRODUCTION, AN ELEMENTARY TREATISE FOR THE STUDENT AND GENERAL READER. By Emil Raymond Riegel, Ph.D., Professor of Physical and Industrial Chemistry, University of Buffalo. 649 pages, illusrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $9.

Many books of this type are before the public. It is an interesting and important subject, the extent of which is such that a very large volume can be prepared if author and publisher are willing. The present work is intended to be a compact account of the large number of industrial procedures in which chemistry has a dominant position. As the author remarks in the preface, the industry is constantly changing, what seemed like a fantastic idea yesterday is realized today. The progress of invention and discovery is constantly influencing the operative conditions. The author notes for instance the importance that the production of radium from Colorado ore had attained making the United States one of the principal sources of this important element; today the Colorado mines are closed, the rich mineral from the Belgium Congo dominating the market. The fusel oil industry was hurt by the adoption of prohibition, but the production of butyl alcohol made by fermentation took its place, but this latter is threatened by the synthetic process. The time-honored industry of the production of methanol by distilling wood is threatened with the extinction by the manufacture of it from water gas. Even more serious changes are indicated. Chile depends in very large part for its operating income upon the export duty on nitrates. The artificial production of ammonia which can be very easily converted into nitric acid threatens the natural sources. Similarly the great advance in the rayon industry may seriously injure the silk production of Japan.

Concerning the general character of the work it is only to be said that it is of the type of the works in this field. It contains a very large amount of information and great variety of topics. It is well illustrated and the chemical principles involved in the process are set forth in detail. Undoubtedly the making of books is an expensive method, but taking into comparison other works of similar size and character the reviewer is not entirely clear as to the necessity for the high price of the book.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 287. Theories of Flow Similitude, by A. F. Zahm. 10 pages, illustrations, quarto, Washington, Government Printing Office, 1928, price five cents.

The laws of comparison of dynamically similar fluid motions are derived by three different methods based on the same principle and yielding the same or

equivalent formulas. In this report prepared for publication by the National Advisory Committee for Aeronautics, in June, 1927, are outlined the three current methods of comparing dynamically similar motions, more especially of fluids, initiated respectively by Newton, Stokes (or Helmholtz), and Rayleigh. These three methods, viz., the integral, the differential, and the dimensional, are enough alike to be studied profitably together. They will presently be treated in succession, then compared.

Report No. 291. Drag of C-Class Airship Hulls of Various Fineness Ratios, by A. F. Zahm, R. H. Smith, and F. A. Louden. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1928, price ten cents.

This report presents the results of wind tunnel tests on eight C-class airship hulls with various fineness ratios, conducted in the Navy Aerodynamic Laboratory, Washington. The purpose of the tests was to determine the variation of resistance with fineness ratio, and also to find the pressure and friction elements of the total drag for the model having the least shape coefficient.

Seven C-class airship hulls with fineness ratios of 1.0, 1.5, 2.0, 3.0, 6.0, 8.0, and 10.0 were made and verified. These models and also the previously constructed original C-class hull, whose fineness ratio is 4.62, were then tested in the 8 by 8 foot tunnel for drag at 0° pitch and yaw, at various wind speeds. The original hull, which was found to have the least shape coefficient, was then tested for pressure distribution over the surface at various wind speeds.

R.

ENAMELS: THEIR MANUFACTURE AND APPLICATION TO IRON AND STEEL WARE. By Laurance R. Mernagh. 234 pages, illustrations, plates, diagrams, 8vo. London, Charles Griffin and Company, Philadelphia, J. B. Lippincott Company, 1928. Price, $7.

The making of hollow ware for culinary and sacrificial purposes is a very early handicraft. Archeologists rely very largely upon the pottery "finds" for judgment as to the age and civilization of primitive peoples. Clay was, of course, the primitive material, but when man began to obtain in some quantity the baser metals, these replaced the clay to a great extent. The liability of iron to corrosion constitutes a great interference with its use and several methods have been extensively adopted to prevent this. Tinning and zincing (the latter universally, but erroneously, known as galvanizing) have been familiar for a long while. Each has its drawbacks. Enameling, that is the coating of the metal with some resistant non-metallic material, has secured wide vogue. The methods have not by any means been free from objection, for certain metals included in the enameling mixture, such as lead, antimony and arsenic render the food cooked therein liable to be seriously contaminated. The action of health authorities has to a great extent eliminated this danger. Enameled ware is now threatened with a new competition, the use of aluminum. This competition has given rise to a charge that aluminum is taken up in the food and the manufacturers of that ware have been busy of late in defending their product.

The work in hand is largely devoted to British methods and the author frankly admits that British practice in this field is not dominating and that America and

Germany are far in advance in both practical and scientific development. Nevertheless, he is evidently familiar with the literatures of both these nations and has included such knowledge in the text, which is comprehensive and clear. It begins with the preparation and treatment of the metal basis, then discusses in fullness the raw materials of the enamels, their formulas, preparation and application. Defects and difficulties are fully set forth and the remedies indicated. It is worthy of note that the British enameling industry which had taken a spurt during the late war, languished thereafter for lack of tariff protection, but this has now been granted a duty of twenty-five per cent. being imposed on imported enameled hollow-ware.

An indication of the listlessness of British manufacturers in the matter of research is indicated on page 14, relating to proprietary substances recommended for picking, it being said that these cost much more than their value. It seems that the larger establishments should consult chemists about this and while exact data might be difficult to obtain good clues would certainly be secured and further experiment would place the user independent of the proprietary products. It is doubtful if the discussion of opacity on pages 45–48 is satisfactory to the general reader.

The book is well printed in clear type with numerous illustrations including plates representing microscopic appearances of the metal-base, machinery and graphs.

HENRY LEFFMANN.

A FIRST COURSE IN PHYSICS FOR COLLEGES. By Robert Andrews Millikan, Ph.D., Sc.D., Director of the Norman Bridge Laboratory of Physics, Pasadena, California; Henry Gordon Gale, Ph.D., Professor of Physics in the University of Chicago; and Charles William Edwards, M.S., Professor of Physics in Duke University. xiii–676–xlii pages, 96 illustrations, 583 figures and 25 tables, cloth 8vo. Boston, Ginn and Company, 1928. Price, $3.72.

The title of this volume, "A First Course in Physics for Colleges," indicates the primary reason for its inception. In the preparation of this course the authors strove to produce a text which might be given in its entirety to first-year college students. To attain such an end and yet not fail to include all the important principles of physics and their corresponding applications in everyday life, the authors have labored in coöperation with other teachers for a considerable number of years. In this respect the book fulfils a long-felt need of freshmen instructors who often are required to assign the more elementary sections in advanced texts. The chapters, thirty-nine in number, cover practically every phase of physical study. Particularly might be mentioned those dealing with conduction of electricity through gases, electrical radiations and radioactivity. At the end of the chapters a number of solved problems, problems for solution and test questions are to be found. A list of supplementary problems will be found in appendix A, while appendix B consists of a number of tables showing conversion factors, properties of solids, liquids and gases, heats of combustion, refractive indices, etc. A most noteworthy feature is that the book contains over ninety portraits of physicists and illustrations of recent achievements in physics. Throughout the text examples are given illustrating the application of physical principles to recent well-known inventions. A few of these are the

Flettner rotor ship, the Sperry gyrocompass, the vacuum tube, the Coolidge X-ray tube and so forth. One glaring mistake appears to have crept in unnoticed. The statement is made that niton, the transformation product of radium, becomes a liquid at 150° C. According to the International Critical Tables the normal boiling point is − 61.8° C.

The book is written in an exceedingly clear style and is so well illustrated that anyone earnestly desiring to improve in an elementary way his or her knowledge of the whole field of physics will find its perusal a source of interest and pleasure.

T. K. CLEVELAND.

HEAVISIDE'S ELECTRICAL CIRCUIT THEORY. By Louis Cohen, Ph.D., Consulting Engineer, Professor of Electrical Engineering, George Washington University, with an introduction by PROFESSOR M. I. PUPIN. ix–169 pages, illustrations, 8vo, cloth. New York, McGraw-Hill Book Company, Inc., 1928. Price, $2.50.

Heaviside, in his Electromagnetic Theory, which appeared in 1899, introduced some novel applications of operational methods in the analysis of transient electrical phenomena which he derived by more or less unconventional methods. The validity of his results was established rather by a process of experimental analysis guided by the intuition of a physicist of exceptional vision than by rigorous deduction. His demonstrations were not easily followed and the difficulty of verifying the general truth of his theorems for many years militated against the wide application that the true merit of his work deserves. Renewed interest in Heaviside's methods awakened by the growing importance of transient electrical phenomena has stimulated in recent years a searching study of his work by several investigators of note with the result that much of the uncertainty of the theory in its original form disappears. The algebraic properties of symbols of derivation are discussed at considerable length including a note on operators with fractional exponents, in that unique work by the late John Perry, "Calculus for Engineers" which appeared in 1897. It is not surprising that a consideration of the operational method should be found in Perry's work for Heaviside quotes him freely in the introductory chapters of the second volume of his Electromagnetic Theory and doubtless the mathematical methods of both authors were mutually familiar. Doctor Cohen's treatise brings the subject within the reach of average technical readers. He explains the Heaviside methods in straightforward understandable mathematical language. The salient feature of the work is the derivation of the famous "expansion theorem" which "applies to all kinds of circuits, concentrated inductances and capacities, or distributed inductances and capacities, giving directly the solution for current and voltage distribution in the circuits; the steady as well as the transient state. Of course, its greatest utility is in the facility it affords for obtaining solutions for transient effects, which may be in some cases very difficult if not altogether impossible to obtain by the usual methods." This derivation is made step by step with meticulous explanation, first for unidirectional electromotive forces, then for alternating electromotive forces. Many applications are worked out at length for a variety of circuits followed by chapters in which the expansion theorem is applied to filter circuits, ocean cables, transmission lines, and artificial lines.

In a final chapter, an analytical examination is made of Heaviside's own derivation of the expansion theorem. An appendix includes a note on Bessel functions, an assemblage of the mathematical formulas used in the text, tables of Bessel functions, hyperbolic functions, and of the error function. Dr. Cohen has left little undone to bring Heaviside's method of dealing with difficult problems of electrical circuits and analogous problems within the reach of every engineer.

L. E. P.

COLLOID SYMPOSIUM MONOGRAPH. Papers presented at the Sixth Symposium on Colloid Chemistry, University of Toronto, June, 1928. Edited by HARRY BOYER WEISER, Professor of Chemistry, The Rice Institute. 341 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $6.50.

Researches in colloid chemistry continue unabated, indeed with increasing force. A system of annual collaboration at American universities has been enforced for several years and the present volume presents a considerable list of papers covering many phases of the physical chemistry of colloidal forms of matter. The general tenor of the communications is of course fairly the same in the several volumes, but the scope of colloid chemistry is so wide and penetrates into the many fields of pure and applied science that each volume shows notable variety. The present volume deals rather largely with vital phenomena and the opening essay on "Living Matter" by Sir William B. Hardy endeavors to throw some light upon the complex problem of life in its various forms. Many details are brought forward and among the conclusions is the statement that biology is in urgent need of real physicists. It might also be said that biology is in need of a broader interest in natural history that is, that the biologists should be something more than the laboratory workers with a few organisms.

The great variety of subjects treated in this volume will make it of use to chemists in many fields, both practical and theoretical. As a closing suggestion of Hardy's paper the following extract will be interesting to teachers:

"Let me give you my ideal of a Biological College. It should have three floors—a ground floor for molecular physics, a first floor for biophysics, and a top floor for cell mechanics. And of the staff the professor of molecular physics should have no responsibility for biology, the professor of biophysics should be a Mr. Facing-both-ways, responsible to physics and to biology, whilst the professor of cell mechanics should be a biologist pure and simple. That college I should expect to provide the new synthesis of knowledge of which biology stands in need."

HENRY LEFFMANN.

CURRENT TOPICS.

Solid Carbon Dioxide. The use of solid carbon dioxide or "Dry-Ice" as a refrigerant is described by Rebeka Dierz (*The Forecast*, 1928, *36*, 79–80, 128). Dry-Ice is compressed carbon dioxide snow. Its value as a refrigerant depends on ease of control, uniform temperature, absence of moisture, and mobility. Its greatest success has been in the refrigeration of perishable foods, especially in small packages during transportation. It has not yet been applied to household refrigeration. J. S. H.

Greenness and Vitamin A in Plant Tissue. John W. Crist and Marie Dye of the Michigan State College of Agriculture and Applied Science (*Scientific Mo.*, 1928, *27*, 166–171) have tested the relative nutrient values of green vegetables and bleached vegetables by means of animal experiments. They recommend that, when the leafy portions of a vegetable are used as foods, green leaves should be preferred to bleached leaves. Apparently some connection exists between the greenness and the vitamin A content. Their recommendation holds true for such vegetables as lettuce, cabbage, celery, and asparagus.

J. S. H.

Electrochemical Oxidation of Benzene to Quinone. Harold Emory Fenimore (Thesis, Graduate School, Univ. of Penn., 1928, 1–24) has devised a new anode electrolyte, involving the use of acetone as the solvent in the electrochemical oxidation of benzene to quinone. Cold benzene extraction has been found the most efficient method for the extraction of the crude quinone from the anolyte. The crude product may be purified either by volatilization in a rapid current of steam or by selective solubility in petroleum ether.

J. S. H.

Stabilization of Cupferron Solution. Frederick G. Germuth (*Chemist Analyst*, 1928, *17*, no. 3, 3, 15) recommends the use of phenacetine (acetylphenetidine) as a stabilizer for the solution of cupferron (aminonitrosylphenylhydroxylamine) which is used as a reagent in analytical chemistry. He finds that addition of 0.05 gram of phenacetine to each 100 cc. of the cupferron solution causes that solution to retain its original value as a precipitant for a period of 20 to 30 days.

J. S. H.

Transition Temperature of Carbon Tetrachloride. JAMES E. McCULLOUGH and HARRIS E. PHIPPS of Oberlin College (*Jour. Am. Chem. Soc.*, 1928, *50*, 2213–2216) have determined that pure solid carbon tetrachloride passes from the cubic to the monoclinic system at a temperature of $-48.54 \pm 0.02°$ C. The hold in the time-temperature curve at this transition point has approximately the same duration as that at the freezing point. This transition point is suggested as a fixed point in thermometry.

J. S. H.

Atomic Weight of Cesium. THEODORE W. RICHARDS and MARCEL FRANÇON (*Jour. Am. Chem. Soc.*, 1928, *50*, 2162–2166) have purified the cesium alums by recrystallization, and then converted them into cesium chloride. Analysis of the cesium chloride by comparison with silver has given the value 132.81 for the atomic weight of cesium.

J. S. H.

Formic Acid. ALBERT SPRAGUE COOLIDGE (*Jour. Am. Chem. Soc.*, 1928, *50*, 2166–2178) has determined the vapor density of formic acid which probably was 99.99 per cent. pure. The results indicate that the vapor is an ideal mixture of two gases, having single and double molecules, respectively.

J. S. H.

Infra-red Absorption by the Sulphydrate Group. JOSEPH W. ELLIS of the University of California (*Jour. Am. Chem. Soc.*, 1928, *50*, 2113–2118) has determined the infra-red absorption spectra of several alkyl and aryl mercaptans and sulphides, using a recording quartz spectrograph. The mercaptans are characterized by a single absorption band at 1.99 to 2.00 microns, which is not given by the corresponding sulphides. This band and another band, which occurs at 3.8 to 3.9 microns, are considered to be due to the presence of the sulphydrate (—SH) group, radical, or bond.

J. S. H.

Electricity Produced by the Friction of Glass with Solid Elements. P. E. SHAW AND C. S. JEX. (*Proc. Royal. Soc.*, A 779.) To get reliable data of the sign and quantity of the electrical charge caused by rubbing two solids together it is necessary to have materials of known composition and physical structure and of definite surface cleanliness. The rubbing should be done by machine to assure uniformity of method. Glass surfaces were cleaned by boiling in chromic or nitric acid for 15 minutes or an

hour respectively and by washing subsequently with boiling water for long periods, even for as much as eight hours. The surfaces of metals were prepared by scraping before each rub with a steel blade newly cleansed in a Bunsen flame. The sign and amount of charge developed were obtained from the charge induced in a sheet of metal beside the glass rod of the experiment. After each rub the two bodies concerned were earthed, the deflection of the electroscope joined to the inductor having been read.

"Some elements never, with any type of glass surface tried, showed negative charge. These are C, Cd, Fe, Pb, Bi, Ag, Cu, Pt, Mg, W. Other elements show ultimate negative charge. These are Zn, Sn, Al, Sb, Ni, Co, Se, As, Cr, Tl, S." It was often the case with the latter group that a positive charge was produced by the first rubs. With the repetition of the rubbing this finally was converted into a negative charge. In every instance of this group the first charge produced was negative when the glass used had been recently fused.

An interesting promise is made: "We shall show in the next paper that in the case of three solids (A, B, C) A may be positive to B; and B to C; and yet C be positive to A. This may occur when the bodies are of different classes, say, metal, textile, glass, which have different physical and chemical characteristics."

G. F. S.

X-Radiation from Gases. A. BJÖRKESON. (*Nature*, July 7, 1928.) In 1924–25 the author, working in the Norman Bridge Laboratory, tried in vain to get X-rays from gases. Now he reports success from Upsala. A beam of electrons was directed on a hole in the upper part of a crucible placed in a vacuum. The heating of the crucible by the bombardment evaporated metallic sodium contained therein. As the vapor rose through the hole it was struck by the electrons and made to emit X-rays. These were detected by their effect on a photographic plate put near the crucible. The rays had access to the plate only through a small hole in a brass sheet, thus producing an effect as in a pinhole camera. The part of the plate corresponding to the stream of vapor was blackened but this change was absent from that portion of the plate when the sodium was removed from the crucible.

When sulphur replaced sodium even more conclusive results were obtained. An electric heater evaporated the sulphur independently of the beam of electrons. The strength of the electron current was 90 ma., and the electric tension 6,000 volts. The X-rays from the sulphur passed through a slit .6 mm. wide into a vacuum spectrograph and fell on a gypsum crystal acting as a

grating. After an exposure of two hours 5 lines appeared on the photographic plate. The two strongest of these correspond to the K_α and K_β lines of sulphur. The others were too weak to have their wave-lengths determined. The comment of the investigator is "So far as I know, this is the first time an X-ray spectrum has been obtained with a gas as radiator."

G. F. S.

Engine Knock and Related Problems. A. C. EGERTON. (*Nature*, July 7, 1928.) Since knocking limits the compression in the internal combustion engine, it reduces the efficiency attainable. "If the compression ratio were raised from 4 to 6 there would be a gain in efficiency of nearly 20 per cent. The world's production of petrol is of the order of 12,000 million gallons per year. A gain of 20 per cent. on the efficiency might save more than 2,000 million gallons of petrol." The addition of benzene, toluene, xylene, etc., to gasoline has long been known to reduce knocking, but to elevate the compression ratio from 4 or 5 to 6 would require the volumes of gasoline and benzene to be equal and the world does not produce sufficient benzene. Midgely and Boyd in their search for some compound more suitable than benzene examined thousands of chemicals and found lead tetra-ethyl. In a Ricardo variable compression engine knocking begins with gasoline alone when a compression ratio of 4.9 is attained. The presence of .1 per cent. by volume of lead tetra-ethyl permits the ratio to reach 5.7 per cent. "About one part of lead tetra-ethyl in 1,500 parts of petrol (about 5 c.c. of ethyl fluid per gallon) will permit the use of a compression ratio up to 6.1, and give an increase of at least 10 per cent.in the power thereby. Furthermore, if all petrol were to be treated with such a 'dope,' it would be quite feasible from the point of view of supply, because it would entail about 40,000 tons of lead per annum, which is not more than 2 per cent. of the world's production of that metal. One molecule of lead in 200,000 molecules of fuel-air mixture is definitely effective."

In the experimental work it was first established that anti-knocks do not influence the location of the detonation of the gaseous mixture. Another line of attack was followed. Weerman had found "that the igniting temperature of petrol, when dropped into a heated iron pot through which air was gently blown, was very considerably raised by the presence of anti-knocks." Mr. Egerton found no elevation of temperature to result from the introduction of lead oxide into the pot but lead vapor raised the temperature considerably "and to much the same extent for a given amount of lead introduced as when introduced as lead tetra-ethyl in solution in

petrol. So the lead part of the molecule dissociated from the ethyl molecule was essentially the active constituent." Other volatile elements were thereupon examined. Al, Mg, Hg, I, P, Au, and Zn proved ineffective while Fe, Ni, Mn, Bi, Se, Tl, Na, Cd, Ca, and Sb caused the rise of temperature. Thallium was, however, the most effective of all and potassium also ranked very high. "It is the metal part of an organo-metallic anti-knock which is mainly instrumental in the action. This metal atom must be in an incipient state of oxidation." That is, the oxide must not exist in relatively large masses.

What is the effect of the anti-knocks on the vapors about to unite? "Anti-knocks definitely slow down the rate of reaction prior to ignition, as curves showing the temperature rise indicate. We have come to the conclusion that ignition starts, not at the surface, but in centers of high energy in the body of the gas. The anti-knock delays combustion not specially at the surface, but by inhibiting the rate of oxidation prevents the setting up of these centers." A table is given of the rise of ignition temperature produced by lead tetra-ethyl. No rise occurs with amyl alcohol, dimethylaniline and carbon disulphide. With benzene it is 18°, with pentane 75°, with valeric aldehyde 380° C. "The combustion of normal paraffin hydrocarbons (which are those constituents of petrol that are most prone to knocking), is more inhibited than that of naphthalenes, for example, such as cyclohexane. Further, there is a very remarkable inhibition of the combustion of aldehydes." "In what stage of affairs in the engine do the anti-knocks have effect? It was found that preliminary oxidation during the compression stroke was much less when inhibitors were present than when they were not present. It was clear that anti-knocks act on the gaseous charge in the stage prior to ignition (and prior to inflammation at the flame front), and delay the initial stages of reaction."

"Knocking appears to be due to inequality in the condition of the charge set up, particularly in regions of high pressure and temperature, as in the neighborhood of hot exhaust valves. This inequality provides regions of high energy, containing molecules in high energy states, where reaction can spread more quickly. Unequal burning gives rise to a vibratory condition of flame. Any influences, such as a higher state of turbulence or cooler surfaces or more even or longer combustion space, which tend to prevent sudden and local rise of pressure, and the setting up of centers of high energy, tend to prevent knocking. Anti-knocks, such as lead ethyl, by inhibiting the processes of combustion which we have seen to occur in those centers, are therefore effective in preventing knocking.

Furthermore, they have been rendered effective by the temperature and oxidation to which they and the charge are exposed during the compression stroke; the charge in the engine cylinder is so affected by its previous exposure to oxidation that the opportunity for a flame to meet regions in a high state of energy is greater than when those previous oxidations have been appreciably inhibited by anti-knocks or other factors."

G. F. S.

The Constitution of Germanium. F. W. ASTON. (*Nature*, August 4, 1928.) By using accelerated anode rays the mass spectrum of germanium was photographed five years ago. From the feeble effects then produced it was possible to identify its three chief isotopes, 70, 72, and 74. Recently volatile compounds of the element obtained from Prof. Dennis of Cornell made it possible to make more accurate determinations. With germanium tetraethyl the three lines previously photographed appeared accompanied by 5 fainter new lines. The isotopes are 70(*c*), 71(*g*), 72(*b*), 73(*d*), 74(*a*), 75(*e*), 76(*f*), 77(*h*), the letters indicating rank in intensity. "It will be noted that of all these mass numbers two only, 72, 73 are peculiar to germanium; the others all form isobaric pairs with the neighboring elements zinc, gallium, arsenic and selenium."

G. F. S.

Caustic Soda Treatment Improves Joint Strength of Certain Woods when Glued. (U. S. Department of Agriculture.) Treating with caustic soda certain species of wood which frequently produce weak or inferior joints when glued into doors, furniture, airplane propellers, and similar articles, improves the strength of these joints, experiments made by the Forest Products Laboratory, Forest Service, show.

A 10 per cent. solution of caustic soda gave the best results as a treating material in the laboratory's tests. Joints of hard maple, yellow birch, white oak, red oak, red gum, black cherry, basswood, and osage orange wood treated with caustic soda showed a decided improvement in strength over joints of untreated wood. While caustic soda solutions weaker than 10 per cent. improved the strength of joints they were not so effective as the 10 per cent. solution.

In the tests made by the laboratory the wood surfaces to be joined were brushed with the caustic soda solution, and after a period of 10 minutes were wiped with a cloth to remove any excess solution or dissolved material, and were then allowed to dry before they were glued. The same grade of glue was used and the density

of the wood tested was substantially the same in every case. When the blocks of wood had been conditioned for 10 days they were cut into specimens of the proper size and their strength tested by a special machine devised for the purpose.

The effect of the caustic soda treatment in improving the strength of glued joints was especially pronounced in certain woods in which "starved joints," those in which the film of glue between the wood surfaces is not continuous, are ordinarily produced, and is well illustrated by the results obtained in the tests of hard maple glued with animal glue. The shearing strength (measure of the capacity of wood to resist slipping of one part upon another along the grain) of a piece of untreated wood glued under favorable conditions was 3,110 pounds, as compared with 1,570 pounds for an untreated piece in which starved joints were manifest, and 3,250 pounds for a piece treated with caustic soda solution, but glued under the same starved-joint conditions. It is quite evident, of course, from these figures that the joints of treated wood were the strongest.

Osage orange wood treated with caustic soda and glued with casein glue showed a shearing strength of over 3,000 pounds, as compared to a shearing strength of only 294 pounds exhibited by the joints of untreated wood. This is an even more striking illustration than the hard maple.

Although the laboratory has experimented with other materials such as ammonia, benzol, hydrochloric acid, bleaching powder, hydrated lime, oxalic acid, and formaldehyde, none of these has been found so satisfactory as caustic soda for treating wood intended for gluing purposes.

Just why treating certain woods with caustic soda increases their joint strength when glued is not known. Evidently, the caustic soda changes the surfaces of the wood fibers in such a way as to cause the glue to stick more firmly.

Attention is called by the laboratory to the fact that while the caustic soda treatment has been found effective in improving the strength of joints produced with certain woods and glues, its use is recommended only where equally good results are unobtainable with standard gluing practice.

Toxic Action of Ethylene Dibromide. In the course of a study of ethyl gasoline by the United States Bureau of Mines, B. G. H. THOMAS and W. P. YANT (*Pub. Health Rep.*, 1927, *42*, 370–375) investigated the action of ethylene dibromide on animals. This compound, which is a volatile liquid with a chloroform-like odor, occurred in the ethyl gasoline in the ratio of 2 cc. per gallon.

Ethylene dibromide was sufficiently toxic to kill guinea pigs and rats, but its minimum lethal dose was not determined. Guinea pigs were made to breathe air containing ethylene dibromide vapor for 1 hour; the concentration of the vapor in the air was such that 0.4 cc. of ethylene dibromide was actually inhaled. Death resulted in 6 to 18 hours. Application of 0.25 cc. of ethylene dibromide gradually to an area of skin 2 centimeters square on the abdomen of rats likewise produced death in 6 to 18 hours. Postmortem examination of the animals, which had died from this acute poisoning, revealed a putrid, mushroom-like odor, and degenerative changes in the vascular system and the viscera, especially in the kidneys.

Ethylene dibromide had approximately the same toxicity as lead tetraethyl, but did not have a cumulative action. Ethylene dibromide is a distinct industrial health hazard, chiefly in its manufacture.

J. S. H.

Edgar Fahs Smith, Elliott Cresson Medalist in 1914, died on May 3, 1928 in the seventy-fourth year of his age. An account is given of his work, and a tribute is paid to his memory by his successor as Blanchard Professor of Chemistry in the University of Pennsylvania, WALTER T. TAGGART (*Science*, 1928, *68*, 6–8). Dr. Smith was educated at Pennsylvania College at Gettysburg, and at the University of Göttingen where he was a pupil of Wöhler. His contributions to chemistry included the determination of the atomic weight of eight elements, researches on a number of the rare elements, the complex inorganic acids, and the history of chemistry, as well as elaborate studies on the use of the electric current in quantitative chemical analysis. For these studies, he was awarded the Elliott Cresson Medal. He also held the Priestley Medal of the American Chemical Society, the Chandler Medal of Columbia University, and twenty-three honorary degrees from nineteen colleges and universities. Dr. Smith was the author and translator of numerous books and brochures in the field of chemistry. He was thirteenth Provost of the University of Pennsylvania (1911–1920) held numerous offices in learned societies, and, at various times, under the state and federal governments.

J. S. H.

Milk From Farm To Refrigerator. Under this title, the PHILADELPHIA INTER-STATE DAIRY COUNCIL has published a brochure of 6 pages describing concisely how a modern city gets its milk supply. A number of interesting facts are given. Milk is now transported from the local receiving station to the city plant in special tank

trucks or in glass-lined refrigerator cars. The plant examination includes organoleptic tests (odor and flavor), and determination of bacterial count, fat content, acidity, and sediment. The storage vats are glass-lined. Filtration is made through very fine cloth. Thorough pasteurization destroys the pathogenic bacteria which cause milk-borne diseases; it does not influence vitamins A and B, but affects vitamin C. In cooling the pasteurized milk, use is made of the principle of the countercurrent. The pipe, by which the hot milk leaves the pasteurizer, is surrounded by a larger pipe through which the cold raw milk flows to the pasteurizer. This process is completed by passage of the pasteurized milk over a mechanically refrigerated cooler. The bottles are washed and sterilized in a machine which may handle 124 bottles per minute. Another machine fills and caps more than 40 bottles per minute. The crated bottles are kept under mechanical refrigeration until placed on the delivery wagon.

J. S. H.

Free Inorganic Radicals. P. WALDEN and L. F. AUDRIETH of Cornell University (*Chem. Rev.*, 1928, *5*, 339–359) have reviewed the literature on free inorganic radicals. The term free is used of these radicals in the same sense as it is applied to certain elements like chlorine. Free chlorine is molecular chlorine Cl_2. The cyanogen radical is CN, and has a valence of 1; free cyanogen is $(CN)_2$. The halogenoid radicals which have been obtained in the free state include cyanogen $(CN)_2$, thiocyanogen $(SCN)_2$, selenocyanogen $(SeCN)_2$, oxycyanogen $(OCN)_2$, and azidocarbon disulphide $(SCSN_3)_2$. Derivatives of the halogenoid radicals are also known; they may be polymeric like ammonium trithiocyanate $NH_4(SCN)_3$, or compounds of halogenoid and halogen like cyanogen chloride CN.Cl, or compounds of the halogenoids with each other like cyanogen thiocyanate CN.SCN. Other inorganic radicals have been obtained in the free state. Thus, nitrogen peroxide, hydrogen peroxide, and hydrazine represent, respectively, two nitrite groups, two hydroxyl groups, and two amino groups joined to each other.

J. S. H.

Butter: Its Keeping and Deterioration. The factors which influence the keeping and the deterioration of butter are reviewed by OTTO RAHN of Cornell University (*Scientific M.*, 1928, *27*, 206–211). Pasteurization of the milk or cream destroys about 99.9 per cent. of the bacteria. When a starter is used to produce sour cream prior to churning, the bacteria of the starter generate lactic acid which destroys *Pseudomonas fluorescens*, a bacterium whose action on the

butter-fat gives rise to rancidity. However, certain molds, like *Oidium lactis* and *Cladosporium butyri* also produce rancidity; they grow better in the sour cream than in fresh cream. During cold storage, the bacteria, molds and yeasts present in butter decrease in number. But, if the butter be made from sour cream, a fishy flavor develops. This flavor has its origin in the decomposition of the lecithin of the butter-fat by the acid derived from the sour cream. This decomposition is greatly accelerated by the presence of metals. Butter churned from pasteurized sweet cream does not contain the acid, and consequently keeps better. While sodium chloride (salt) has a bactericidal action, it also catalyzes the decomposition of the lecithin. Unsalted butter has excellent keeping qualities provided the microörganisms which produce rancidity are absent. Butter has an extremely complicated physical structure; and this structure probably influences its keeping and deterioration.

J. S. H.

Tests for Chromium. NORMAN M. STOVER of the University of Alberta (*Jour. Am. Chem. Soc.*, 1928, *50*, 2363–2366) has compared the ether-hydrogen peroxide test and the diphenylcarbazide test for chromium with each other. The latter test was found to be far more sensitive. When a dichromate solution was acidified with sulphuric acid and shaken with ether, a positive reaction for chromium (blue color in the ether layer) was given by as little as 1 part of chromium in 1,250,000. Portions of the dichromate solution were acidified with certain acids, and a solution of diphenylcarbazide in alcohol containing 10 per cent. of acetic acid was then added; a positive reaction for chromium was the production of a color in 10 minutes; the color depended on the amount of dichromate present, being deep red with relatively large amounts and a distinct violet with small amounts. The minimum amount of chromium detected by the diphenylcarbazide was 1 part in 12,500,000 in the presence of citric acid, 1 part in over 71,000,000 in the presence of acetic acid, and 1 part in 100,000,000 or even 250,000,000 in the presence of sulphuric acid.

However, when these tests were applied in the usual course of qualitative analysis, the minimum amount of chromium detected by the diphenylcarbazide was approximately 1 part in 1,000,000 in the presence of acetic acid, while the ether-hydrogen peroxide test failed to show the presence of 1 part in 250,000.

J. S. H.

Determination of Potassium as its Iodoplatinate. ALFRED T. SHOHL and HELEN B. BENNETT of Yale University (*Jour. Biol.*

Chem., 1928, *78*, 643–651) recommend the quantitative determination of potassium as its iodoplatinate, either by titration or colorimetrically. Potassium chloroplatinate is precipitated. This precipitate is converted into potassium iodoplatinate by treatment with potassium iodide. The aqueous solution of potassium iodoplatinate has a deep wine-red color.

In the colorimetric method, the color of the unknown is compared with that of a standard. This method may be used when less than 1.6 milligrams of potassium are present in 100 cc. of solution. If the concentration of potassium exceeds this value, the solution must be diluted before comparison of the colors. The maximum error of this method is 4 per cent. of the potassium present.

In the volumetric or titration method, the potassium iodoplatinate is titrated with 0.01 normal sodium thiosulphate solution, using a micro burette calibrated to 0.01 cc. The end point is the transition to a lemon-yellow color, which is probably due to the formation of potassium iodoplatinite. The reaction supplies its own indicator. This method is convenient for amounts of potassium ranging from 0.4 to 1.0 milligram with a maximum error of 2 per cent. of the potassium.

The two procedures may be combined. The titration is made. The reduced lemon-yellow salt is oxidized to the red salt by means of hydrogen peroxide and hydrochloric acid; and the colorimetric determination is then carried out. Salts of iron and copper, ferricyanides, alcohol, exposure to brilliant sunlight, and excessive acidity are disturbing factors.

J. S. H.

New Test for Industrial Lead Poisoning. CAREY P. MCCORD (*Bull. U. S. Bureau of Labor Statistics* No. 460, 1–33, 1928) has devised a new test for industrial lead poisoning. The human blood normally contains 4,500,000 or 5,000,000 erythrocytes or red blood cells per cubic millimeter. Immature or basophilic red cells do not usually exceed 1,000 per cubic millimeter of blood; they are designated basophilic since they contain granules which are stained selectively by certain dyes like methylene blue and brilliant cresyl blue. In 145 normal adults, the number of basophilic red cells per cubic millimeter of blood was usually less than 1,000, and never exceeded 5,000. The number of these cells may be increased in certain physiological and pathological states. The entire research included the examination of the blood of 1,045 persons, of whom 550 were exposed to lead, and 50 were cases of clinical lead poisoning.

In the absence of other conditions characterized by a high basophilic red cell count, such a count indicates either lead ab-

sorption or lead poisoning in a worker exposed to lead. A progressive increase in this count in such a worker indicates imminent clinical lead poisoning. In frank cases of lead poisoning, this count usually ranges between 7,000 and 50,000, and rarely exceeds 100,000.

The high count decreases to a normal value with the excretion of the lead under treatment. When this count reaches 6,000 or 7,000 in a worker exposed to lead, especially if the increase be progressive, treatment for lead poisoning should be considered.

This test may be used to determine the degree of lead hazard in various departments of a plant or industry. It has demonstrated that many workers commonly regarded as unexposed, such as clerks and office workers, may absorb much lead and become potential cases of lead poisoning. This is especially true when the lead derivative is in the form of a dust.

J. S. H.

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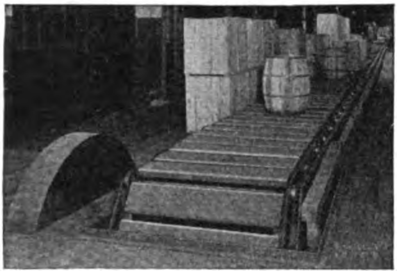

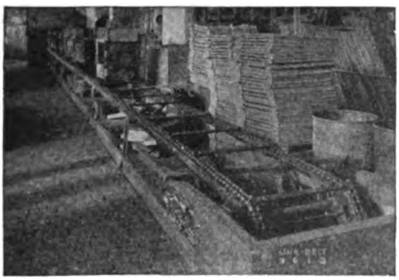

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Members of the Institute shall consist of those engaged or interested in scientific pursuits or in the application of science in the mechanic and industrial arts. Members shall be classed as follows: Honorary and Corresponding, Endowment, Life Contributing, Resident, Non-resident, Holders of Second Class stock.

Honorary and Corresponding members shall be nominated by the Board of Managers and shall require for their election four-fifths of the votes of the members present at any stated meeting of the Institute at which their nomination may be acted upon. They shall not be entitled to vote or hold office. All other members shall be elected by the Board of Managers.

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The Elliott Cresson Medal (Gold Medal).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

The George R. Henderson Medal (Gold Medal).—This medal is to be awarded for meritorious inventions or discoveries in the field of railway engineering.

The John Price Wetherill Medal (Silver Medal).—This medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

The Edward Longstreth Medal (Silver Medal).—This medal is awarded for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance.

The Louis E. Levy Medal (Gold Medal).—This medal is awarded to the author of a paper of especial merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

The Walton Clark Medal (Gold Medal).—This medal is awarded to the "author of the most notable advance in knowledge or improvement in apparatus, or in method concerning the science or the art of gas manufacture or distribution or utilization in the production of illumination, or of heat, or of power."

The Certificate of Merit.—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with The Franklin Institute the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity."

For further information relating to these awards apply to the Secretary of the Institute.

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